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Executive Summary

**A Document forming Part of the Portfolio
for submission to The Degree of 'Engineering Doctorate'
at the University of Warwick**

The development of process models

John Ferrie

**Submitted May 1997
Revised May 1998**

Executive Summary

1.0 Introduction

Shortly after Privatisation in 1987, Rolls-Royce faced the enormous business challenge of increasing shareholder value against the background of the worst global economic conditions imaginable. The end of the Cold War and the resultant demand for a peace dividend halved defence spending in Western countries. As a direct consequence, huge amounts of highly capable industrial capacity in Europe, the United States and the former Soviet Union became immediately free and began seeking new markets world wide. Successful advances in Rolls-Royce aero engine technology had by the late 1980's produced engines with much longer operating lives and thereby reduced requirements for maintenance. This led directly to both reductions and delays to the companies previously experienced revenue earning streams. The industrial world went into a deep and protracted recession. During this period of the early 1990's the commercial airlines in the USA lost more money than had been made in the industry's entire history. The problem was compounded by emerging industrial countries targeting aerospace as a growth sector and seeking to acquire capability and create new indigenous capacity through investment and participation in new product programs.

With market growth curtailed, prices reducing under severe competitive pressure, unrelenting customer demands for better products and investors demanding increasing growth in shareholder value, every aspect of the company's business was under intense pressure simultaneously to reduce cost and improve performance. Rolls-Royce therefore needed to deploy the most powerful techniques available to improve business performance and profitability.

As part of the adoption of Total Quality in the late 1980's I had identified that improvements to business performance could only come through improvements to Products and their associated Processes of Design and Manufacture in response to better understanding of Customer needs. Also, these improvements demanded better training to improve the performance of the People operating in the Business. This early belief led me directly to the application and early success of Business Process Re-engineering within the Industrial and Marine Business for which I was then responsible. Building on previous successful but limited application of Systems Engineering to the introduction of Cellular Manufacturing within the company (early support for which was provided by Lucas's Dr John Parnaby), development of these techniques was led by me and applied to non-manufacturing aspects of the business. This work convinced the Aerospace Group Board to accept my proposal to apply Business Process Re-engineering across the Aerospace Group in the belief that it held the prospect of producing the required improvement in business performance. This initiative became known as Project 2000.

In the course of Project 2000 a series of generic process models was developed by me to provide the redesign effort with a simple but robust framework. These models were developed in response to individual situations and demands from Project Teams to me as the Project Director for guidance in the absence of an overall map or blueprint. The principles on which the models were based enabled multiple redesign projects to act semi-autonomously within the business without the presence of an expensive management overhead or the need for strong central control.

The idea that Businesses like cellular biological systems in Nature might function by a limited number of relatively simple evolutionary recursive fractal processes developed from my discussions with my good friend Dr David Pollock, a research biologist. David encouraged my understanding and provided recommended readings of the processes at work in biological systems. By comparing business systems with biological systems an awareness emerged of the strong similarities and patterns in the underlying processes. This exchange of ideas not only provided analogies and parallels but also provided me with valuable clues as to the sequence and functionality of the fundamental processes at work. This insight proved extremely valuable and helped me in my subsequent model building. Most particularly, the sequence of *Mutation - Replication - Competitive Selection - Mutation - Replication -etc.* in the Natural world appeared to have a direct equivalent in the Business world of *Design -*

Build - Use - Modify/Redesign - Re-build - etc. This sequence is inherent in Demming's quality cycle of *Plan - Do - Check - Adjust - Re-do - etc.*

The function of biological DNA to act as a template for storing and transmitting the information for the construction and control of a living organism appeared to me to have possible application to the problem of redesigning a large complex entity. Chaos Theory and its central notion that complexity can emerge from the repeated application of simple patterns or processes, i.e. 'fractals', in non-linear systems appeared from my observations to hold true in business situations. These ideas from Nature provided me with a conceptual springboard for my development of an alternative to the orthodox top down linear deterministic approach to organisational change. The business process 'fractal' models which I developed in the course of Project 2000 are the subject of this submission for the Engineering Doctorate degree.

2.0 The Benefits

The advantages of using the concept of fractal models applied to process reengineering can be summarised as follows:-

- a) In a large complex business a conventional analytical approach often leads to the generation of large difficult to comprehend models. Exploiting fractals and chaos theory, the same simple patterns or models can be used universally throughout the

enterprise significantly simplifying and reducing the amount of analysis effort required prior to redesign.

- b) Mapping the enterprise as a large fractal emphasises the process nature of the business. Ties with functional or organisational based thinking are broken.
- c) The use of a limited number of simple process models reduces the information which needs to be communicated in transforming the organisation to a process based philosophy. The simplicity of such models increases their acceptance and use within the business.
- d) The use of fractal models allows all processes, no matter how deeply they are buried within the enterprise to be examined with equal rigour.
- e) The repeating fractals interface with each other in a consistent manner throughout the entire enterprise model. It is hence easy to trace paths of information flow and isolate the interfaces between all processes. This is an essential requirement when designing information systems. My most recent effort to produce a 'fractal' model of a complete business is shown for illustration in **Figure A** below.

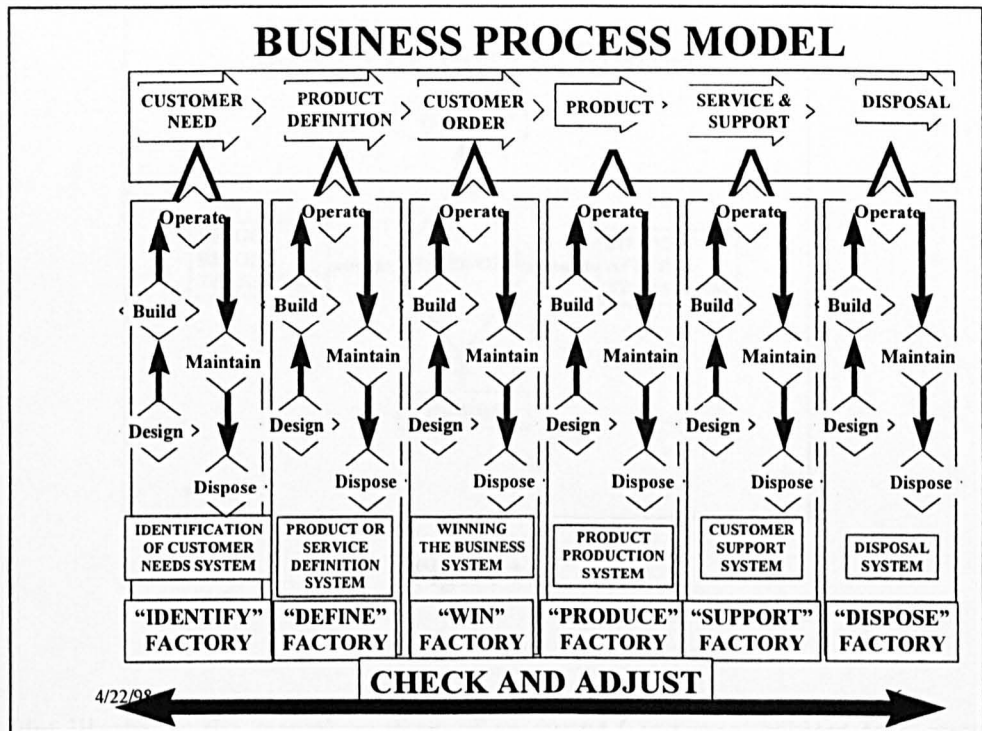
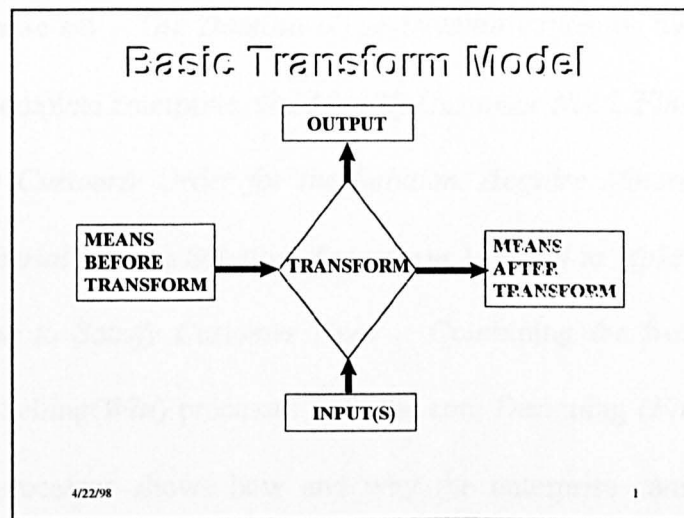


Figure A

3.0 The Models

My basic set of models are described briefly below:-

a) **The Basic Process Element - The 'Transform':**-The basic notion of a *process* is expressed by the fundamental *Transform* model which is shown as **Figure 1**.

**Figure 1**

The model illustrates the transformation of an *input* (*material*)object to a state of different added value to become an *output* (*product*). This transformation utilises a *means* which itself changes state as a result of the '*transform*' it has performed. The *Means* may have a higher value in its after state if useful learning has taken place but more usually the *Means* will have a lower value since energy will have been expended and functionality reduced through usage and normal wear and tear.

b) The Foodchain:- The sequence of relationships between subsequent processes within an enterprise is expressed as the notion of a supply or value chain. Each process is fed by a supplier process and feeds a customer process. The similarity between processes in a business and food sources in the natural world has lead this scenario to become known as a *food chain*.

c) **The enterprise set - The Domino** :-The *Domino* expresses the set of processes which form a complete enterprise; viz. *Identify Customer Need*, *Find Solution to meet the Need*, *Win Customer Order for the Solution*, *Acquire Material and Means to Transform Material into the Solution*, *Transform Material to Make the Solution* and *Deploy Solution to Satisfy Customer Need* . Combining the front end Marketing (*Identify*) and Selling(*Win*) processes with the core Designing (*Find*) and Making (*Transform*) processes shows how and why the enterprise came to exist. The interfaces between processes are expressed as are the interfaces between the levels in the food chain. The *Domino* is shown in **Figure 2**.

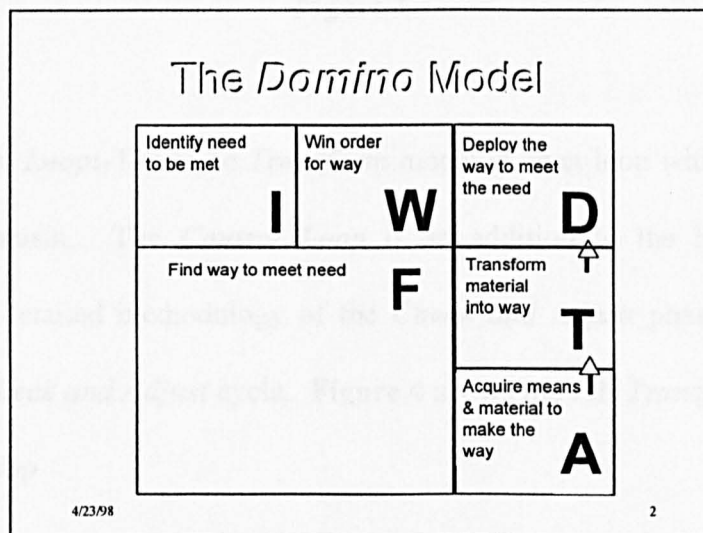


Figure 2

d) **The Life Cycle - The 'W'**:-The '*W*' introduces the dimension of time to map the product *life cycle*. It positions the *process set* within the *food chain* against a base

generated by a product *life cycle*. It identifies the key interfaces between customer and supplier processes. This is illustrated in **Figure 3**.

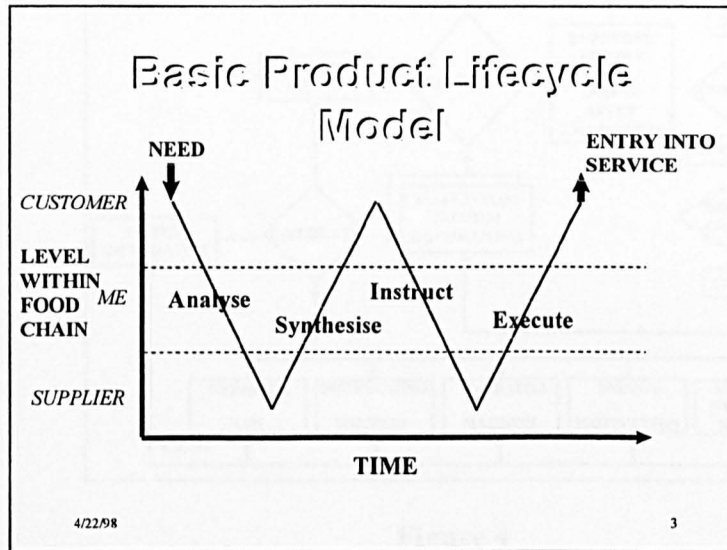


Figure 3

e) **The Control Loop:-**The basic *Transform* model is open loop with no feedback or control mechanism. The *Control Loop* is an addition to the basic model and expresses the detailed methodology of the *Check and Adjust* phase of Demming's *Plan - Do - Check and Adjust* cycle. **Figure 4** shows the full *Transform* model with the *Control Loop*

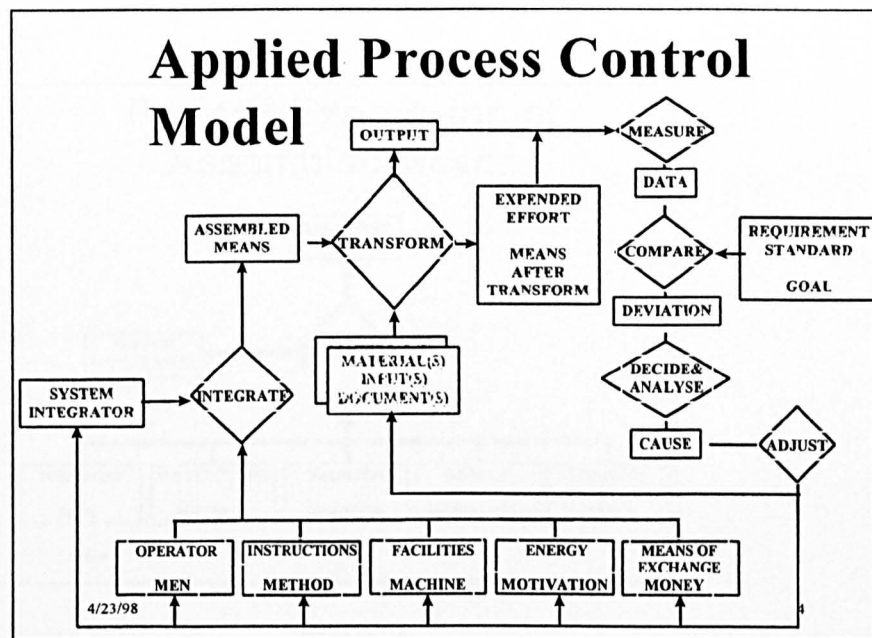


Figure 4

Natural selection in biological systems assures healthy and vigorous development of species. Successful development and learning are captured in the DNA of surviving species and are passed on in subsequent reproductive events. In Business this is paralleled by the working of the competitive free market. The **Control Loop** provides the mechanism for evolution and organisational learning in Business systems.

f) **The 6Ms**:-The final adjunct to the basic transform model consists of the detailed expression of the '**Means**' of the transform. The **Men**, **Machines**, **Methods**, **Money** and **Motivation** making up the '**Means**' together with the **Material** input to the transform become colloquially known as the **6Ms**. The model of the '**Means**' which illustrates the constituent components is shown in **Figure 5**.

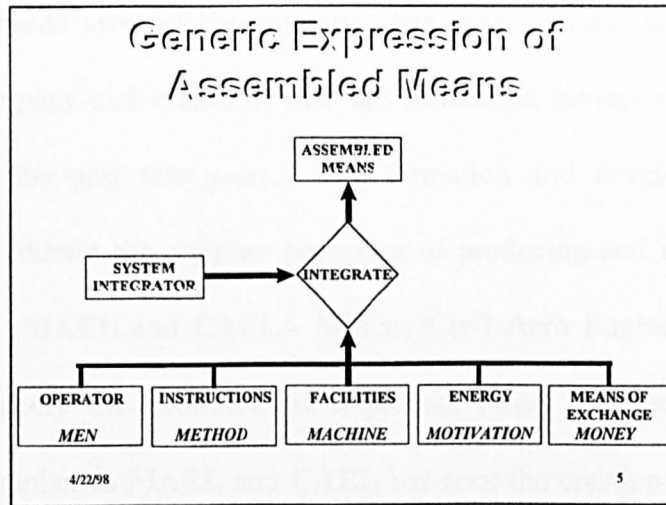


Figure 5

4.0 Results

The Business Process Re-engineering initiative which started life as **Project 2000** is now being continued by a fresh initiative known as **Better Performance Faster (BPF)**. **BPF** is making extensive use of the models and concepts detailed in this submission. I have assisted **BPF** teams deploy and use the models both to analyse existing processes and to develop new process definitions. I am presently responsible for the process of Program Management within Rolls-Royce and am guiding a **BPF** project (IPM)to implement this approach to managing the business. A key deliverable of IPM is a definitive model of the Aerospace Group :- i.e. the **Enterprise**. This DNA type map of the processes which comprise the **Enterprise** will underpin the development and application of powerful IT solutions to significantly improve business performance.

This process based view of the enterprise has been continuously promoted by me within the company and externally and has influenced several major organisational changes over the past few years. The formation and development of Trading companies to address the separate processes of producing and selling Military and Civil Engines (**MAEL** and **CAEL**:- Military/Civil Aero Engines Ltd) is one such example. Equally the evolution of a process based organisation for the main engineering supplier to **MAEL** and **CAEL** has seen the creation of single entities to design and make engine subsystems. These sub products are integrated further by **MAEL** and **CAEL** into propulsion systems. Redesign of the Integrated Product Definition process (Project *Derwent*) is wholly based on the methodology described. I was closely involved in this effort and assisted Phil Ruffle, now the company Technical Director, in numerous process redesigns. This has resulted in a significant step change reduction in engine development timescales and costs. In the recent UK Strategic Defence Review I chaired a working group which looked at the organisation of the Procurement Executive. I used the models to convince the various participants that the Business Process Model could be applied with equal effect to their activities. This resulted in specific recommendations being accepted to establish and operate integrated project teams throughout the life cycle of new weapon systems to deliver reduced cost and lead time.

My use of the models in managing improvement in my recent two posts has contributed significantly to the results achieved. In Manufacturing the models guided the restructuring of the UK based operation to reduce factory floor space by some two million square feet and reduce the workforce by over three thousand during a two year period whilst maintaining output. My consistent application of the process based approach when I was the Managing Director of the Military Engine Business doubled Turnover and Profit and reduced the number of dissatisfied Customers by a factor of three over a three year period. In my current appointment as Executive Vice President Business Operations in the companies US subsidiary Allison, the models have been used to produce short term improvements in business performance and Customer satisfaction. A major reorganisation is also underway and the models are being used to gain understanding and acceptance of changes from the top management team.

5.0 Further work

The *Process Models* will continue to form the basis of all Business Process Re-engineering process analysis and synthesis within Rolls- Royce. They will contribute to the intellectual foundation and provide useful tools for the company to work out how to maximise its performance. As more individuals become conversant with these methodologies then it is only natural that such process based philosophies will be developed further. The major outstanding challenge at the moment is the teaching of these models to the various people who need to use them. As yet there is no standard method by which the models are taught. With my support and direction, training aids

are being produced and more user friendly forms of the models are being developed without loss of rigour or intellectual content. The models also provide a powerful framework from which to develop dynamic functional models of business processes and enterprises. These later models hold the prospect of useful real time simulations for planning and training purposes.

THE DEVELOPMENT OF PROCESS MODELS

**A Project Report forming Part of the Portfolio
for submission to The Degree of 'Engineering Doctorate'
at the University of Warwick**

John Ferrie

Submitted May 1997

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Any endeavour of the nature of this submission owes its genesis and evolution to a huge number of contributions from different individuals. It is impossible to recall the many separate contributions insights and inspirations provided by numerous colleagues friends and mentors over the past seven years leading up to this point. A few must be mentioned by name due to the huge debt of gratitude I feel I owe them for their patience and tolerance as I wrestled with the logic of what now seems trivially simple, but at the time seemed a complex chaotic maze defying analysis. Here are just a few of the many contributors, in no special order than what comes to mind on this flight from Japan, to whom I would record my appreciation.

- To Alex :- A fan of models who agonised with me in the early days as the initial logic emerged.
- To Phil :- Whose Brilliant designer mind ensured the soundness of what developed and who applied it with such success.
- To John :- Who developed in parallel and still provides the human psychology so vital to successful application of the theory.
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To Wal:- From whom I have learned so much about information technology and data.

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To My board :- Who still endured 'Ferries' F'ing Fractals' at every session where colleagues improvement of business processes is discussed.

To the hundreds who participated in Project 2000 and the current BPF teams who are applying the theory and developing its power.

And last but by no means least - Martin - whose youthful vigour and bright intellect have made possible the preparation of the submission from all points on the globe thanks to the power of modern communications and his patience.

To all - my thanks - it was and still is a team effort

I hereby certify that this work is entirely my own unless explicitly stated to the contrary.

John Ferrie

Terminology

Process	A definable set of activities which together achieve from a known starting point a measurable output to satisfy an agreed customer need.
Transform	The change of state that has occurred between the input and the output of the process.
Means	The device whose functionality delivers the transform capability.
Input	The entity - often the output of another process- upon which the means acts resulting in a Transform.
Output	The resultant entity produced by the application of the means on the input.
Enterprise	A business entity functioning at a given range of levels within the supply chain consisting of many interrelated processes.
Fractal Model	A replicating model infinitely expandable both inwardly and outwardly with reference to itself.

Chapter 1

1.0 The Requirement and Subsequent Development of Process Models

Subsequently detailed in this submission are the process models which have been developed during over 100 process studies involving the author in all facets of Rolls-Royce Aerospace business. A description of these models should however be prefaced with an understanding of the way in which these models were developed and the reason behind so doing.

The introduction of Total Quality Management within the Rolls Royce Aerospace Group and the Business Process Re-engineering initiative Project 2000 brought to light a fundamental problem. The strong engineering ethos which pervaded the thought processes of the organisation dictated that a top down model of the enterprise be provided. If it would be possible to produce such a model of the processes as they existed it would be so large and complex as to be impossible to usefully comprehend. Yet to be able to analyse and redesign business processes whilst maintaining their interfaces with other dependent processes it is necessary to have a clear understanding of exactly what constitutes a process. Some concept of how each of the fundamental processes interrelated would also be a valuable tool. This tool could then help comprehension of the business in process terms. However the process nature of the business was not understood. Attempts to approach the issue in an evolutionary way were thwarted by activity or organisational views that many held of what the business comprised.

As a production man by background it was natural to think in terms of a number of activities performed in succession to achieve an end result. As a trained engineer my thinking was that all processes were sequential.

From an activity point of view, individuals might describe the company as being in the business of designing and making gas turbines for aeronautical applications. However this notion of the company is not sufficient for business process re-engineering. The business process which Rolls Royce Aerospace Group operates is to provide aeronautical power and thus satisfy a given customer need. This might involve the design and building of gas turbines but this is only a subset of the whole Rolls Royce Aerospace Group business process. It is essential that this difference is recognised by all those involved in Business Process Re-engineering initiatives.

To illustrate the difference between *process* and *activity* thinking we might consider a simple manufacturing process. In this example a single piece of metal is formed into a product in 3 operations:-

1. Stamp metal template
2. Paint metal template
3. Form metal template into product shape.

Let us assume that the finish of the end product is poor due to the paint cracking as the metal was formed in operation 3. From an activity point of view, considerations might lead to investigations into new types of paint which could stand being flexed and bent.

However if the whole manufacturing sequence is viewed as one process then the resultant thinking might simply result in the painting and forming stages being reversed in order. This example although trivial illustrates the potential of taking a holistic view of activities i.e. a systems or process view of the world at any level.

To assist the process reengineering effort a “template “ around which people could think and communicate was considered useful. It was believed that “process models” would best satisfy the need. However these “models” must be robust. Testing of early models against real processes subjected to reengineering efforts, rapidly developed the models and proved their utility.

Not everybody thinks or comprehends in the same way. For some individuals a check list might be more useful. However check lists do not stimulate the broader appreciation of processes that is required for what is essentially a design effort. A model provides a visual and mental picture of the process to promote lateral thinking. This type of thinking is required by any Business Process Re-engineering initiative.

The models provide a flexible frame work within which to think about a specific process. To understand the workings of a process without any mental stimulation whatsoever is extremely difficult for most individuals. However a model can act as a guide to find a path through the inherent complexity of interdependent processes. A model provides an intellectual spring board from which to examine the process nature of a business.

Models are required at various levels of complexity:-

- 1 A process
2. The process set which comprises a business
3. The sequence of processes required throughout a products lifecycle.
- 4 The combination of a process with its control system and the interrelationship of different levels within a business.

Starting from some initially notional models these evolved into a basic set which subsequently have proved adequate for analysis of all business situations. They can be used for both synthesis and analysis during reengineering efforts.

The subsequent chapters describe these models.

Chapter 2

In this section a description will be given of the models that have been developed and used by the author to enabling the modelling of the processes that exist within the Rolls Royce Aerospace Group. The models provide a way of untangling the inherent complexity of such an organisation. Only when the workings of an organisation are adequately understood can an attempt be made to change and improve constituent processes. The models are tools that enable user to do this.

2.0 The Enterprise Model (Domino)

Before describing any particular model it is first necessary to be acquainted with the fundamental entities of a business.

2.1 A Process

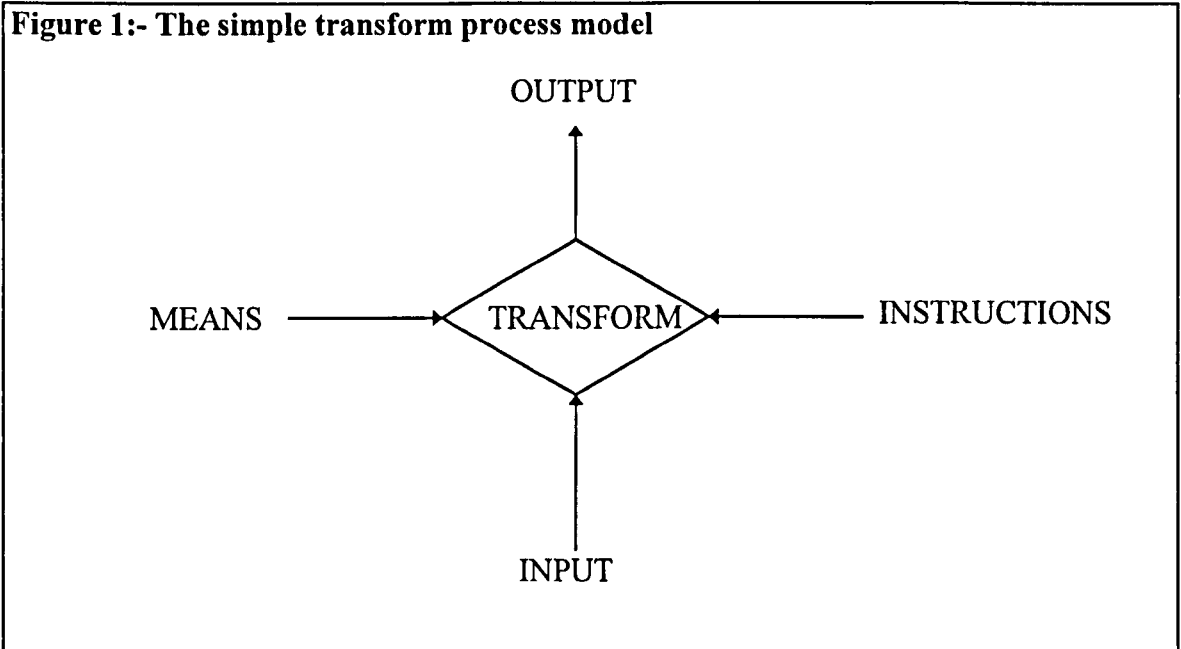
Within the Rolls Royce Aerospace Group the following definition of a process is used:-

"A definable set of activities which together achieve from a known starting point a measurable output to satisfy and agreed customer need." (P2000 Handbook)

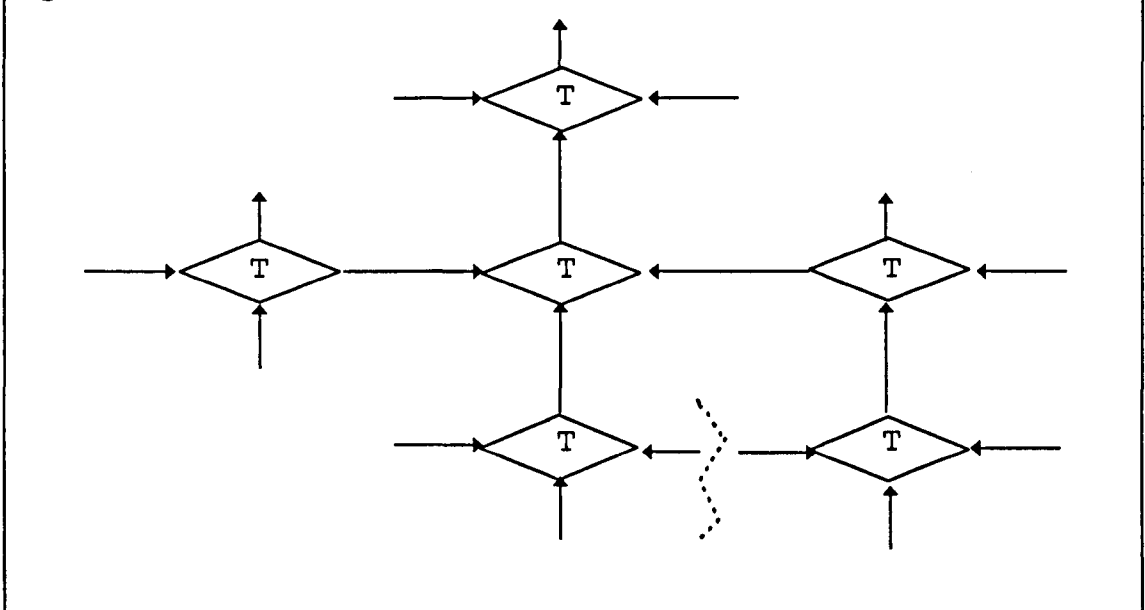
This definition has proved to be robust, rigorous and succinct. A process adds value to an acquired sub-product to deliver a product in order to satisfy an identified customer *need*.

A verbal description of a process is always characterised with a verb, a doing word. A simple notion of a process is that a *means* acts on an *acquired input* according to a set of

instructions. This then *delivers* an *output* to which value has been added in comparison to the *input*. Diagrammatically this can be expressed as in figure 1



This tool, although simple, enables the user to model large areas of business operations. Its simplicity facilitates its use to express complex relationships between multiple processes. When analysed from a process point of view, the resultant map provides the user with an understanding of how the business functions. It does not reflect in any way the organisational structure that may exist within the company. Figure 2 demonstrates how the model can be used to express the relationships between successive and neighbouring processes.

Figure 2:- Transform models inter-linked

2.2 The Customer

A second entity of which a solid understanding is crucial is that of a *customer*, arguably the most important individual, participant or stakeholder in the enterprise.

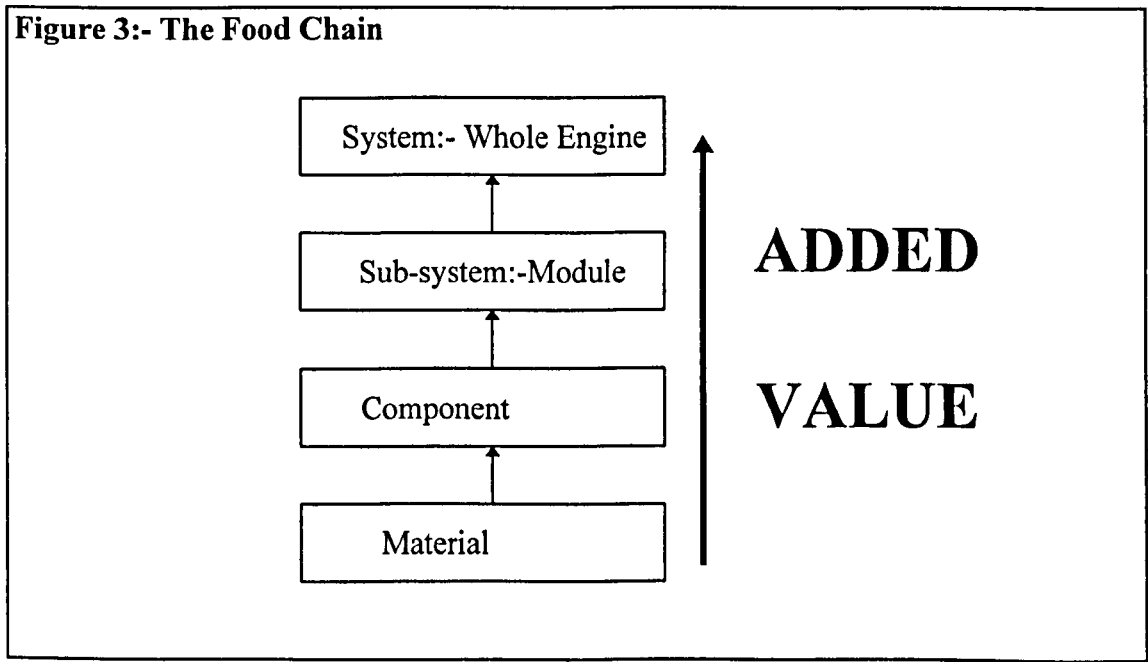
The customer no matter where they feature within the overall business process will have a functional requirement. It is this requirement that must be identified in order to produce an accurate model of a process. For example, a customer who buys a camera is not ultimately concerned with buying a camera. What they require is the functionality of being able to store and retrieve images in a convenient format. They would not automatically buy a camera if this function was possible by some other means. This is a rigorous concept and should always be applied when modelling the creative or productive definition processes with a business.

Although the customer may utilise the supplied product in a number of different ways the underlying customer requirement remains the same. The customer might use the functionality of the product directly. In the case of a hairdresser who is supplied with a hairdryer they use the functionality of the product directly to dry their customers hair. However in the case of a hair dryer manufacturer who is supplied with 13 amp mains plugs, they simply assemble the plug to the hair dryer during the manufacturing process. They do not themselves use the main functionality provided by the plug. Hence, although the customer may use the supplied product in a number of different ways this does not effect the fundamental relationship between supplier and customer. The product is still supplied to meet the particular customers functional requirement.

It should be noted that with the civil aerospace industry there exists a complex relationship between airline, airframer and engine manufacturer. Although it is the airframer who assembles the engine into a complete aircraft, it is the airline that is the ultimate customer of the engine manufacturer. The airline is able to select engines independently of the variant of aircraft. This relationship might suggest that this scenario is an exception but it exists in many circumstances. It underlines the fact that no matter who the customer is they have need of the functionality of the suppliers product. The fundamental relation remains the same and thus should be treated accordingly.

2.3 The Food Chain Analogy

Examining figure 2 it can be seen that the output of one process provides the input to another process. A series of processes then form a chain. Examining this concept with respect to the Rolls Royce Aerospace Group we see that the main product of this enterprise is a gas turbine propulsion system. This product can be decomposed into smaller sub-systems such as the compressor, combustor and turbine. These subsystems can then be broken down further into individual components such as compressor blades, combustion chambers and turbine blades. Finally examining these individual components we see that these themselves are made of material i.e. metal which is the lowest conceptual level within the chain of processes that exists within the Rolls Royce Aerospace Group. This supply chain or product work break down structure is shown diagrammatically in figure 3.

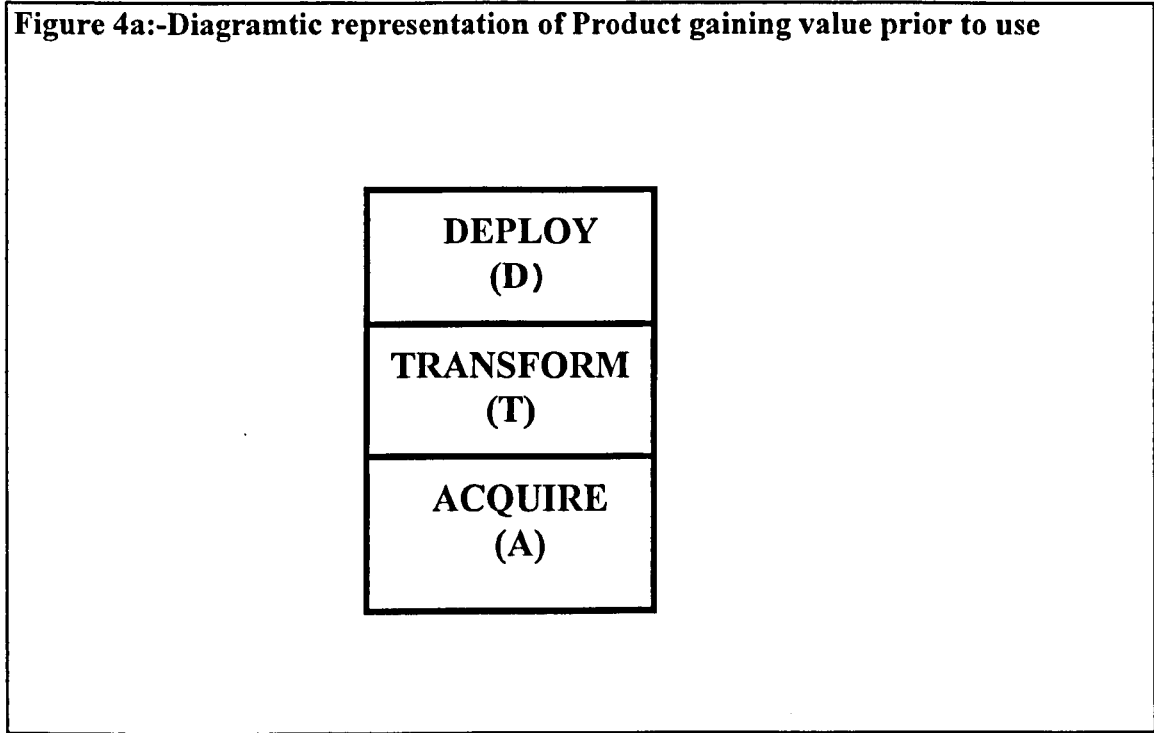


Examining this chain we see that at each stage the individual process provides a product for a “customer”. Equally each product within the chain only delivers its complete functionality when the total system is assembled. The gas turbine only provides useful value adding power when it has been delivered to the airline as part of an aircraft and is in service flying passengers.

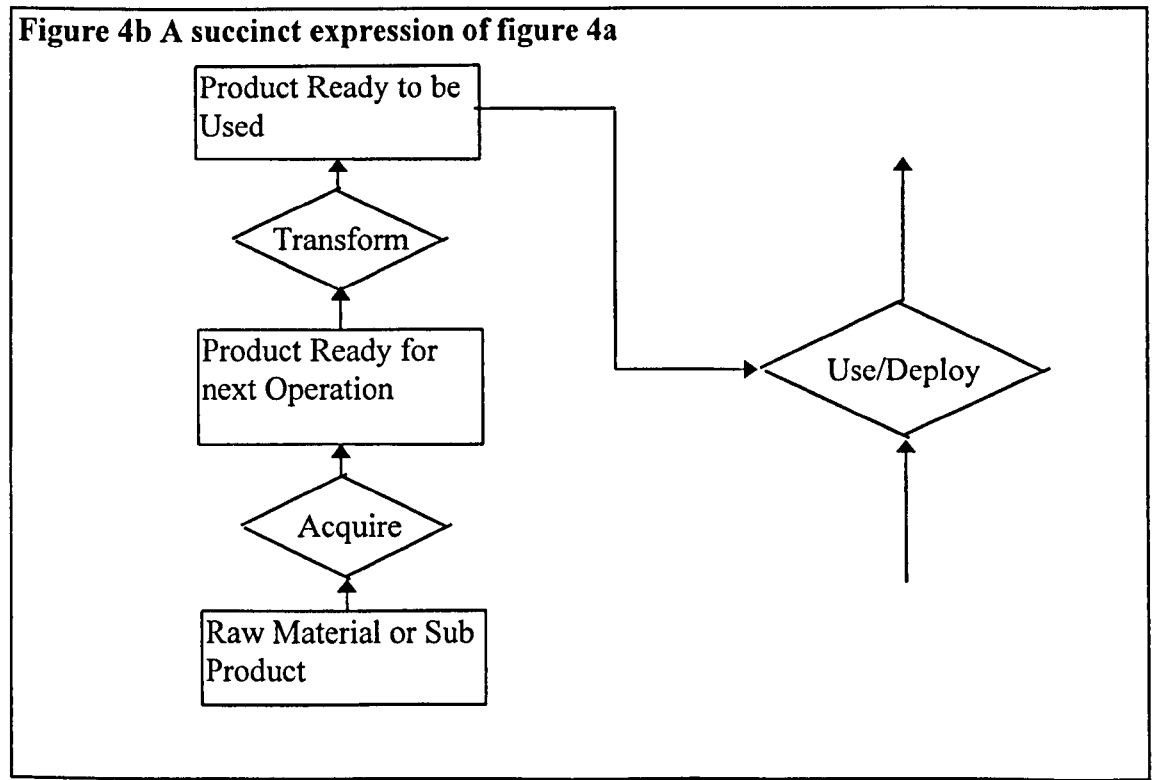
Looking at these chains of processes we see that they resemble the food chains that occur in nature. For instance insects eat leaves and are in turn eaten by voles which are then eaten by owls and so on. Hence these process chains have come to be known as *food chains* due to the analogy which has been drawn with nature.

2.4 The Structure of a Process

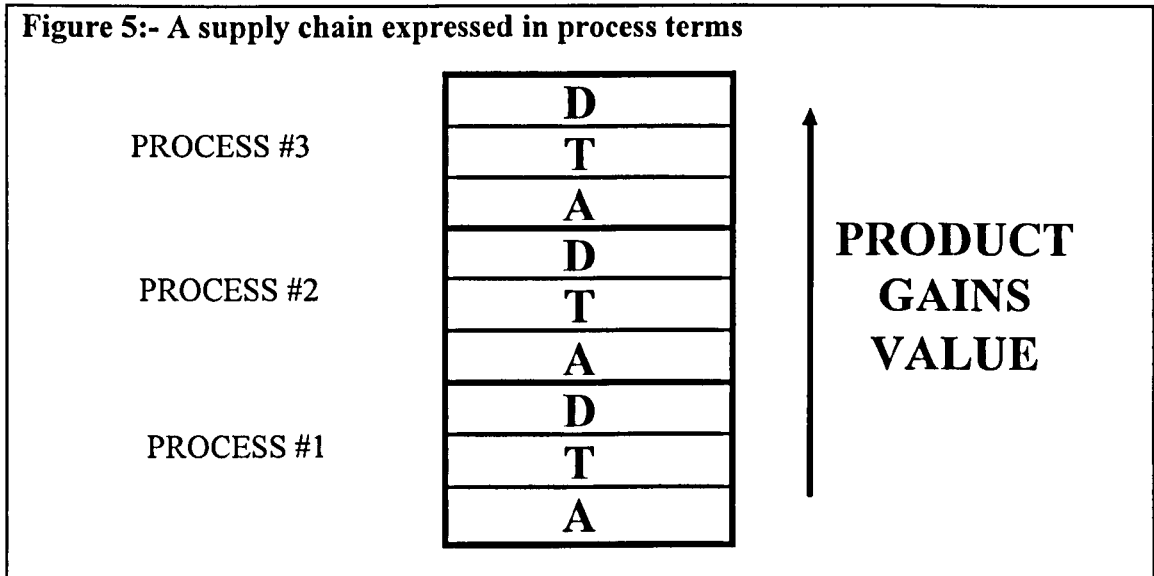
At any level within an established business process chain the operator is looking to accomplish the link at an optimum level. The actions with which they are concerned are essentially *acquire*, *transform* and *deploy*. These form part of the chain that adds value to the product as it progresses up the food chain. The activities of acquiring the subproduct and deploying the product can be more fully expressed by using the transform model. Figure 4a shows a diagrammatic representation of the notion.



A summary of this can then be succinctly expressed diagramtically as figure 4b



A chain of value adding processes might be simply expressed as



So here we have part of an overall model that shows how the value adding actions of processes are linked and act upon the product. However to provide a complete model of a business enterprise we need to answer three fundamental questions. .It will then be possible to identify the remaining key elements of the model that provide a full representation of a business in process terms.

A. Why should this process exist?

The reason the process exists is that a potential customer has need of a functional requirement. The process has been designed to provide a product that will fulfil this functional requirement. So the whole reason for the acquire, transform, deploy actions of a process existing is to satisfy this need. It can hence be seen that *Identifying The Need* of a customer is the initiating action.

B. How did the process come to deliver the functionality of Acquire, Transform and then Deploy?

To answer the second question the activities of acquiring, transforming and deploying were designed to fulfil the specific customer need. The action of designing these activities has enabled the process designer to *Find a Way* of satisfying that customer need. The action of *Finding A Way* to meet the customer need is the second step in the process.

C. Are there any other ways in which the customer can fulfil their functional requirement?

The customer will be faced with a number of different products offered by suppliers to meet the functional need. A decision will need to be made as to which product is most favourable. The customer will then inform the chosen supplier that their product is the one which they wish to *acquire*. The enterprise will have *won the order* to supply the customer. Ideally this part of the overall process takes place after a *way* has been found.

Hence looking at the answers to the above question we now see that we have a model of a business enterprise comprising 6 discrete activities or processes. It has been found by repeated testing that these are the essential activities in any business enterprise and have been identified as key tools for Business Process Re-engineering initiatives such as Project 2000 (Appendix A) A simple description of each of the six activities follows.

1. ***Identify the Customers Need.*** (I) The action of this step is to establish what the customer wants to be able to do. It hence requires knowledge of the customers and the

system in which they exist. This system should be modelled in order to ensure that the need is fully understood.

2. ***Find a way to satisfy the need.*** (F) This is a major value adding activity within any business enterprise. It will provide a series of plans and instruction which will;

- a) Define the product
- b) Define the operations to manufacture the product.
- c) Define the functionality of the material to be acquired to make the product..
- d) Define the functionality of the means to be acquired to transform the material.
- e) Define the way in which the product should be operated to deliver its functionality.
- f) Define the way in which the product should be maintained to restore functionality following degradation from use.

3. ***Win the Order (W):***-The customer agrees to the method of satisfying their need and gives their agreement to proceeding .

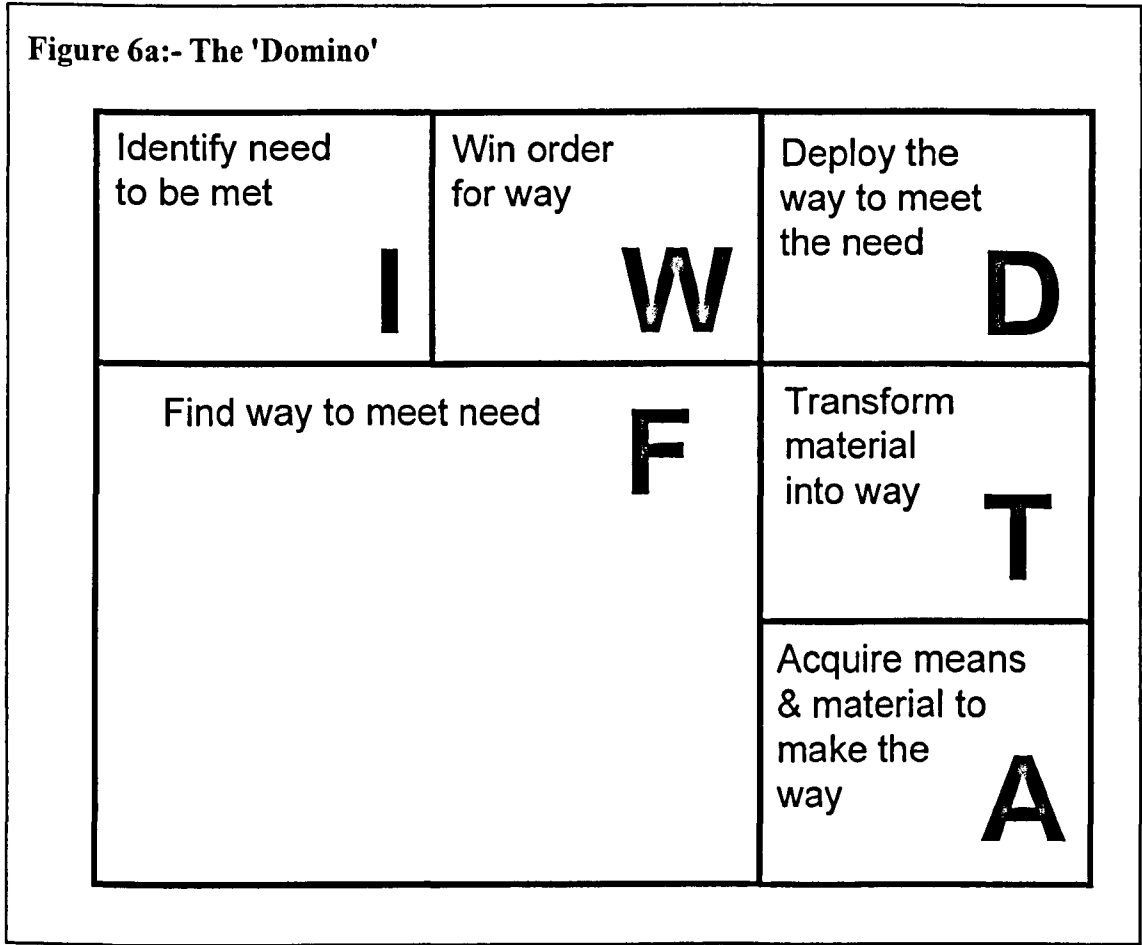
4. ***Acquire(A):***- This is the step of the sequence when those things required to carry out the process as identified in the *find a way* stage are obtained. All the materials to

which value will be added are acquired during this stage. Also acquired at this stage are the means by which the value adding will be accomplished.

5. **Transform (T)**:-The action of executing the instruction to use the means to transform the material into the product. This is a pure “Do” activity and in the ideal process presumes perfect instructions, material and means. In practice non-conformance is usually present and needs to be dealt with. This is addressed in a later model through the action of a control process providing feedback.

6. **Deploy (D)** :-Deliver all the functionality of the product to satisfy the customers need. This can be expressed in terms of cost, quality and delivery i.e. value, function and time.

The model comprising of these 6 fundamental processes has been labelled the *Domino model*. It has been shown by repeated use to be both rigorous and robust.(see Appendix A) It aids those who use the model in understanding the relationships between particular inputs and outputs and therefore the workings and relationships between individual processes. It can be succinctly expressed in a diagrammatic format as shown in figure 6a.



The time sequence of the “Domino” will be addressed in a later chapter which describes the life cycle model. However it is helpful at this point to indicate the sequence in which the Domino elements relate (figure 6b) .

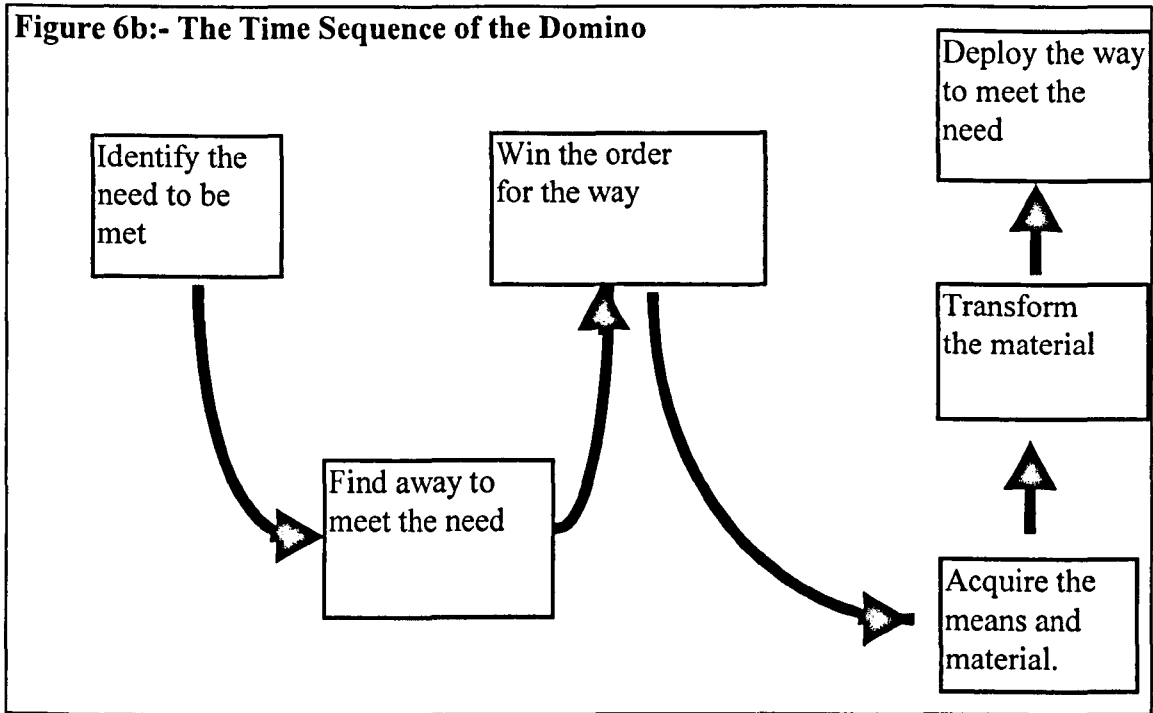
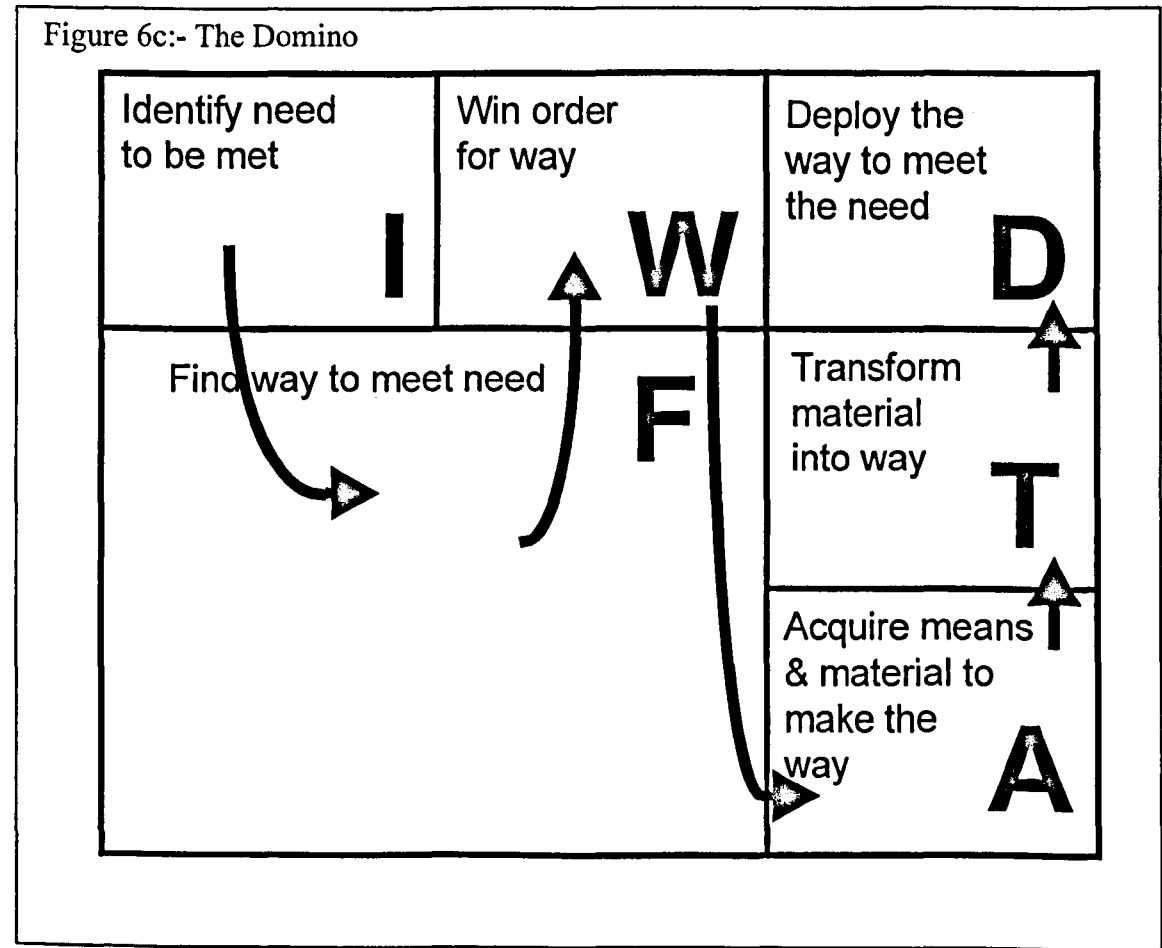


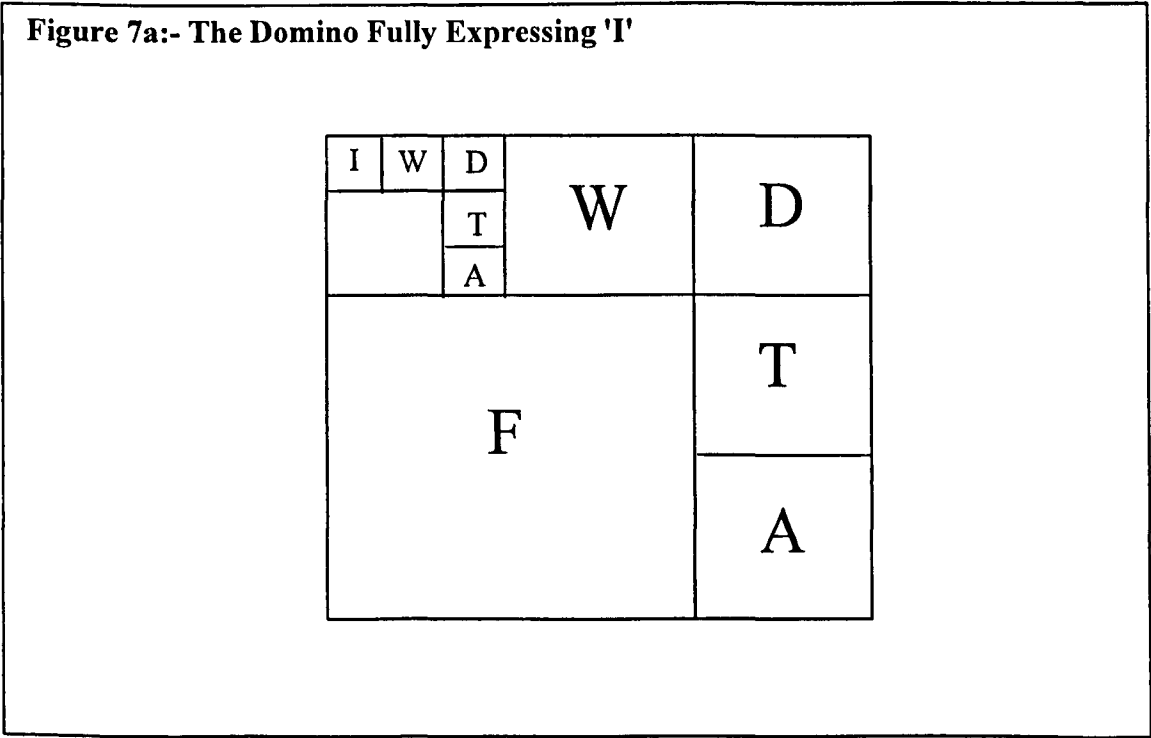
Figure 6c shows a way of expressing this on the Domino.



2.5 The Fractal Nature of Processes

The domino model conceptualises a business enterprise as a set of 6 processes. Each individual process can be considered as an enterprise in its own right . However *Transform* is pure DO. The *transform* within a process is the physical execution of the way found to meet the identified *need*. All actions associated with setting up this transformation are carried out by one or other of the other 5 processes which make up the enterprise.

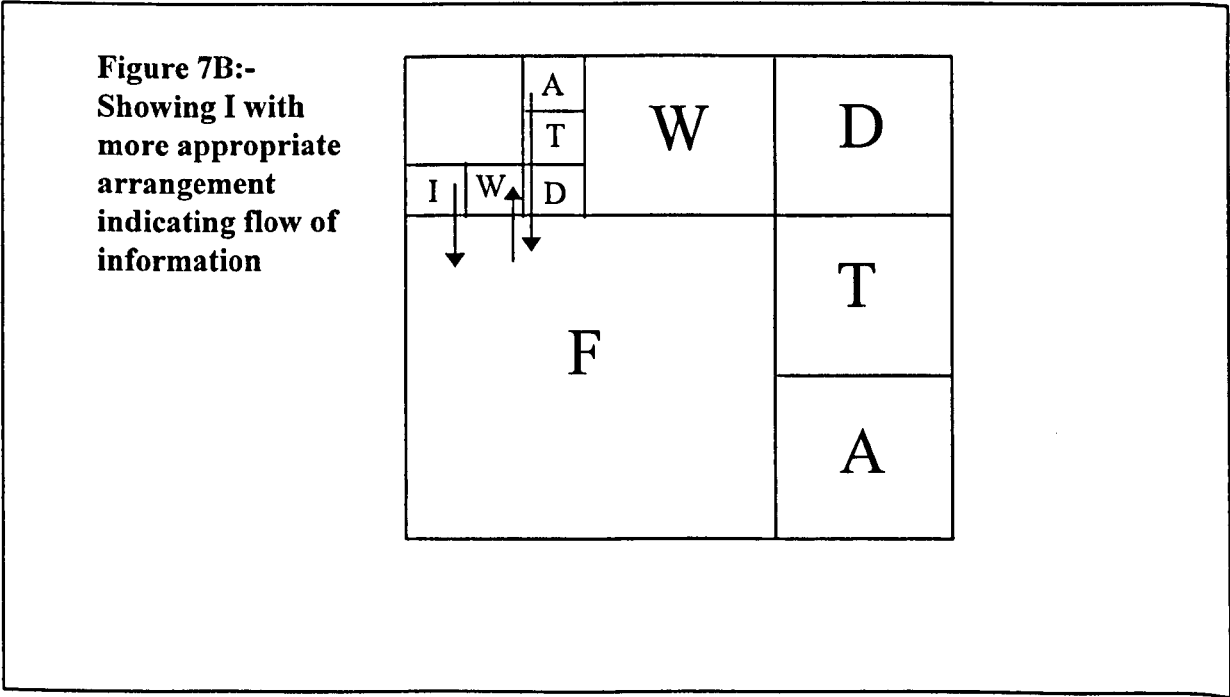
To illustrate this concept, we will apply it to the first sub-process within the *Domino* model *Identify The Need*. As shown in figure 7A it can be broken down into six constituent sub-processes.



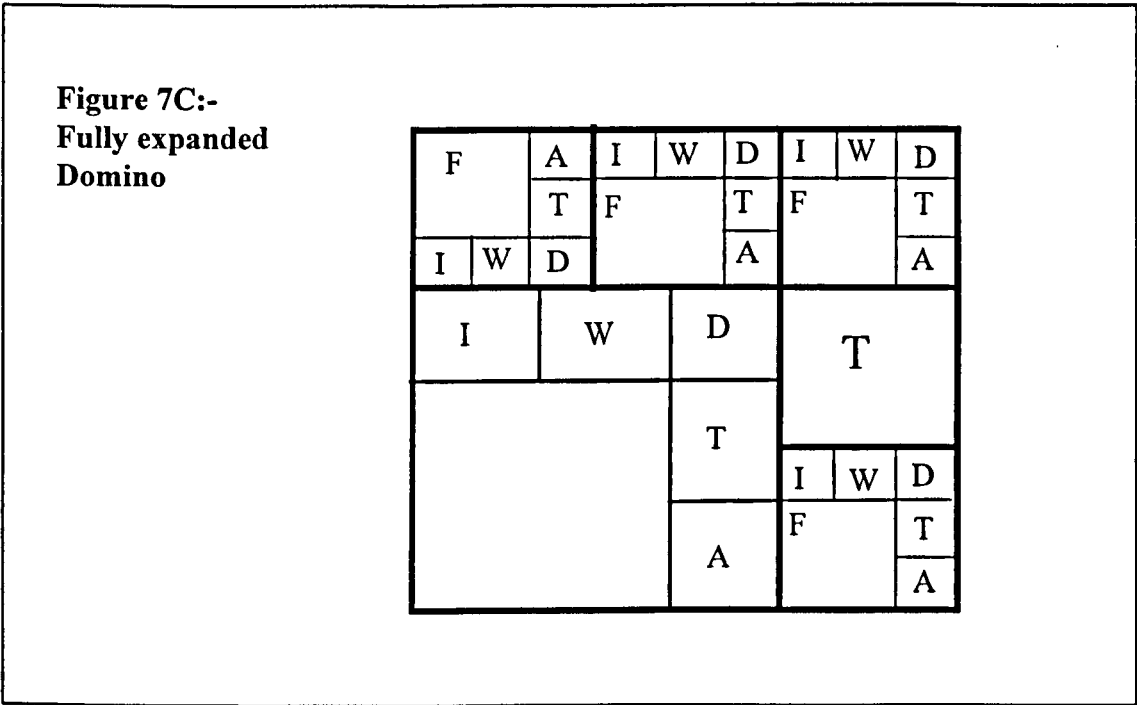
Consequently the 6 sub-processes can be described as:-

- 1. **Identify the need:** The need is to provide a method or procedure to identify the need of the customer.
- 2. **Find a Way:-** This is to define the method of identifying the *need*.
- 3. **Win Order:-** Agree the method to be adopted to identify the customer's *need*
- 4. **Acquire:-**Acquire the means to be used to identify the customer's *need*.
- 5. **Transform:-** This is the execution of the method which will then yield an identified customer's *need*
- 6. **Deploy-** This need is used by the recipient to be able to correctly translate *need* into a product requirement in *Find a Way* i.e. the user of the result of I is F.

Figure 7B shows a more appropriate arrangement of this *domino* to convey better the flow of information within the big domino.



When this concept is applied to the complete model the result is shown in Figure 7C.

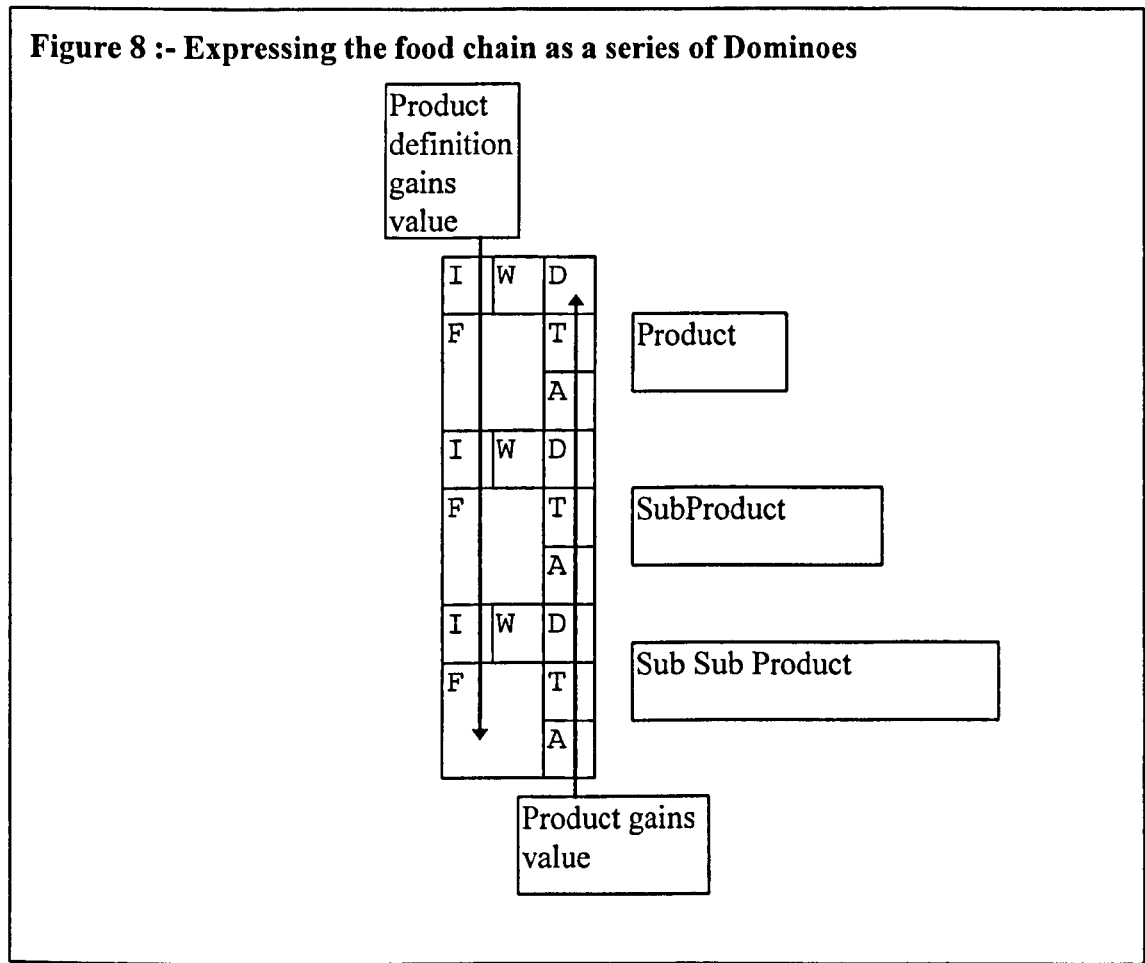


It follows that within the expanded model each subprocess can be broken into further Fractals ad infinitum. Experience shows that the fractal concept is most useful when from a given level of study of the business process, this decomposition is limited to a single pass yielding a set of 30 sub- processes. The main focus in re-engineering projects usually concerns the F and its resultant T. Consequently the notion of the F-T pair or the design -make pairings becomes a useful concept.

2.6 Revisiting the Food Chain Concept

With an understanding of the Domino Model it is now possible to look at how this model can be used to express the relationship between the chains of processes that exist within a

large enterprise. Expressing the food chain as a series of Dominoes is illustrated in Figure8.



Examining figure 8 it can be seen that the chain of processes can be split vertically into 2 sections. Firstly the right hand sequence of sub-processes of *Acquire, Transform* and *Deploy* adds value as the actual product passes up the chain. The left hand part of the chain comprises the *Identify the need, find a way* and *win the order* aspects of the model. Here value is added as the need passes down the chain and progressively becomes more fully decomposed and hence the product becomes more defined. In order to more fully appreciate the reason for expressing the model in this particular format, further investigation of the *find a way* sub-process is required. At any level *find a way* defines

what shall be transformed and how. By this action, time, cost, profitability and quality attributes of the product are determined. This therefore defines the nature of the product that is *acquired* from the supplier:- the enterprise below in the food chain. In anticipation of this definition of requirement the supplier will have identified a need to provide a product. Consequently it will embark upon finding away to meet the need of the customer - the process above itself in the food chain. Thus all processes in the food chain will downwardly start to operate in the *Identify a need* stage and rapidly progress to *finding a way* to meet this *need*. With all of the levels simultaneously in operation in the *Find a Way* stage the model expresses the concept of 'concurrent engineering'. The interface in the model between *Find A Way* of the customer and *Win The Order/Identify the Need* of the supplier is representative of the dialogue that occurs between supplier and customer during the product definition stage of a process. This concept will be more fully elaborated by the life cycle model in chapter 3.

2.7 Summary

The Domino has been shown to be a powerful model . It has been used to understand the complex interdependency of processes that exist throughout the Rolls Royce Aerospace Group as well as to model processes within many individual parts of the business. Such a robust tool has made possible the conduct of a multi - point Business Process Re-engineering initiative. This has been carried out with the confidence that the process nature of the business has been understood and can be communicated.

Chapter 3

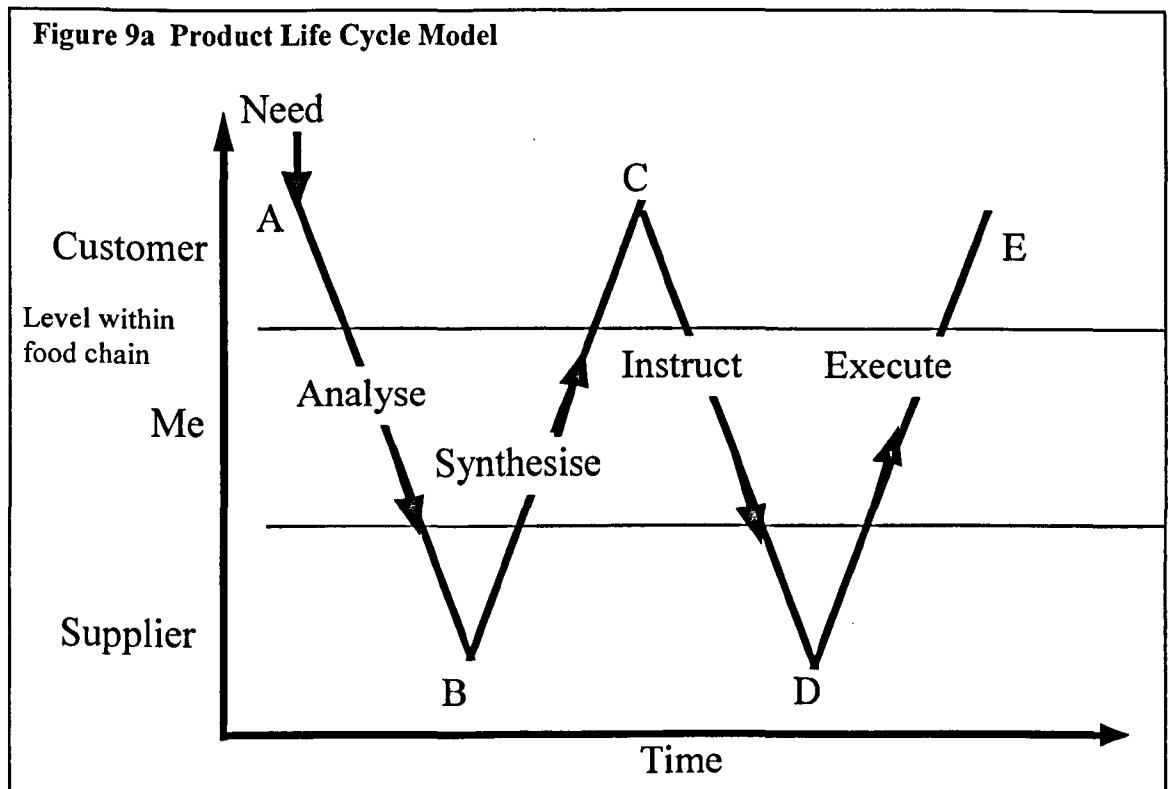
3.0 Beyond the Domino:-The Product Life Cycle Model

The Domino Model has already been described in chapter 2 and has been shown to be a very robust and succinct way of describing an enterprise in process terms. However this particular model does not adequately deal with the concept of time. Additionally the concept of product flow through the food chain is not immediately apparent from such a model. What follows is a description of a model which illustrates the complete product life cycle in a conceptual form. As will become readily appreciated this model has become known as the "W" model.

3.1 The W model

Figure 9a and 9b express the notion of the operation of a food chain over time.

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The customer *need* is at the highest level in the food chain. This *need* is ultimately satisfied by the product flowing up the food chain through a series of value adding processes. However information will have to flow both up and down the food chain in order that the final production of the product is possible. Examining the process conceptually we see that initially the *need* of the customer is analysed and understood. This *need* is decomposed by asking such questions as 'What do I have to be able to do in order that the customer can do what he wishes?'

Taking a real business example, a customer ; the aircraft constructor; wants an engine to provide a specified amount of thrust for a given operational cost . This requirement is analysed to decompose the *need* in order to define the functionality of each engine sub-system, each component and then finally the material. This analysis or decomposition of *need* is continued until the most fundamental elements of any product are identified and

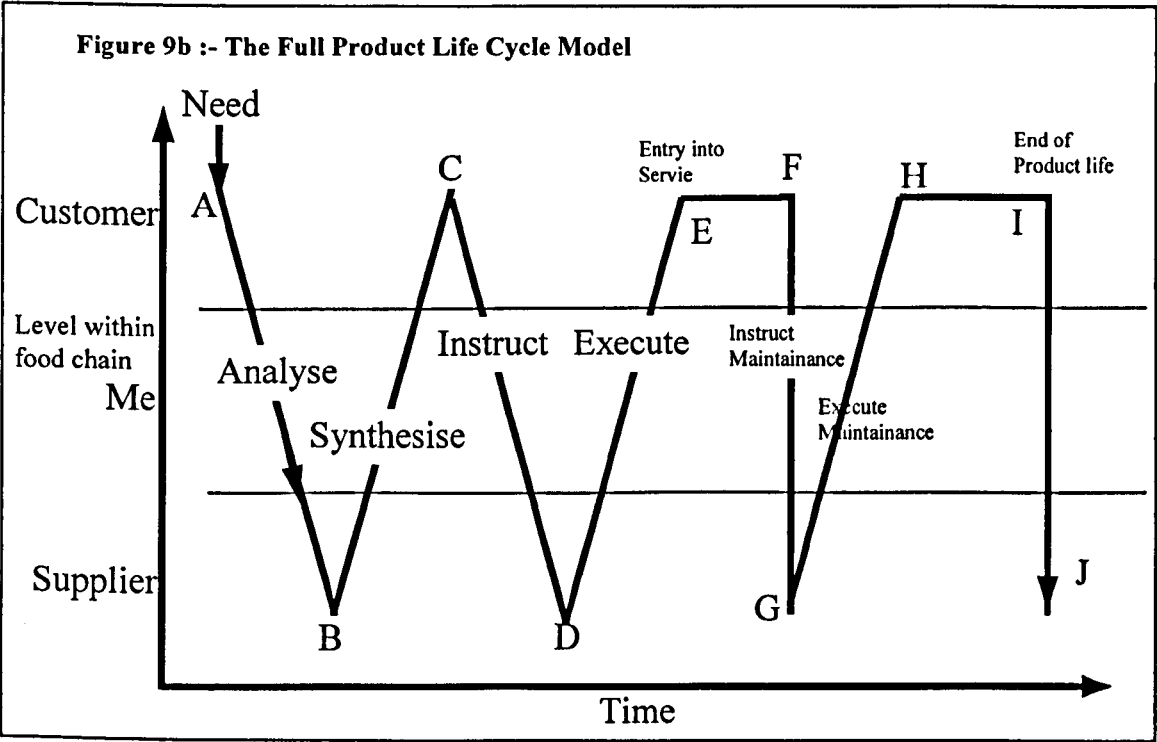
deemed to be obtainable. This part of the product decomposition is represented by sections A to B on the model (figure 9a).

As time progresses each section of the food chain puts forward '*A way*' it has found to provide the required functionality of the customer. The result is a definition of what can be produced by the food chain. This synthesis or virtual realisation of the product is a result of decisions that have been taken sequentially during product definition as the best ways are found to deliver the product functionality. This part of the product design phase is represented by sections B to C in the model.

Eventually this will result in a definition or model which can be presented to the customer. When the customer agrees to "buy" the proposed product, then a cascade of instructions back down the food chain can occur (section C to D) These instructions will have been formulated during the synthesis phase i.e. B to C. The consequence of the instructions being executed will be the product. This real construction of the product up the food chain is shown as Section D to E. Hence the model is as described in figure 9a. The reason why it has become known as the "W" is obvious!

The model consists of four distinct phases. *Analyse, Synthesise, Instruct, and Execute*. The first three stages of the life cycle do not result in the generation of any tangible product. The product is not realised in a physical form until the final *execute* stage of the life cycle. Up until that point it exists only as data or information flowing up and down the food chain i.e. in virtual form.

The basic 'W' model needs to be expanded beyond the design and build phase to describe the full product life cycle process and is shown in Fig 9b.



The product starts to deliver its full functionality i.e. gets used, beyond point E. Figure 9b shows this notion. The product is required to sustain an adequate level of functionality to continue to satisfy the customer *need*. When this is no longer possible action is required either to replace or maintain the product. In the case of maintenance a sequence of disassembly and reassembly will normally occur. Ideally this will already have been anticipated and the instructions created during the initial product definition phase (section A to C). If not they will be required before maintenance can be carried out. In the model the former is assumed as best practice. This maintenance process is shown as F,G,H and may be repeated several time during the life cycle of the product.

The final stage of the model describes the continued service of the engine until its useful life has been consumed. At this point disposal will take place by some form of decomposition (Section I to J) This should have been anticipated during the initial definition phase and at least outline instructions or plans predefined which are then executed.

3.2 Competition.

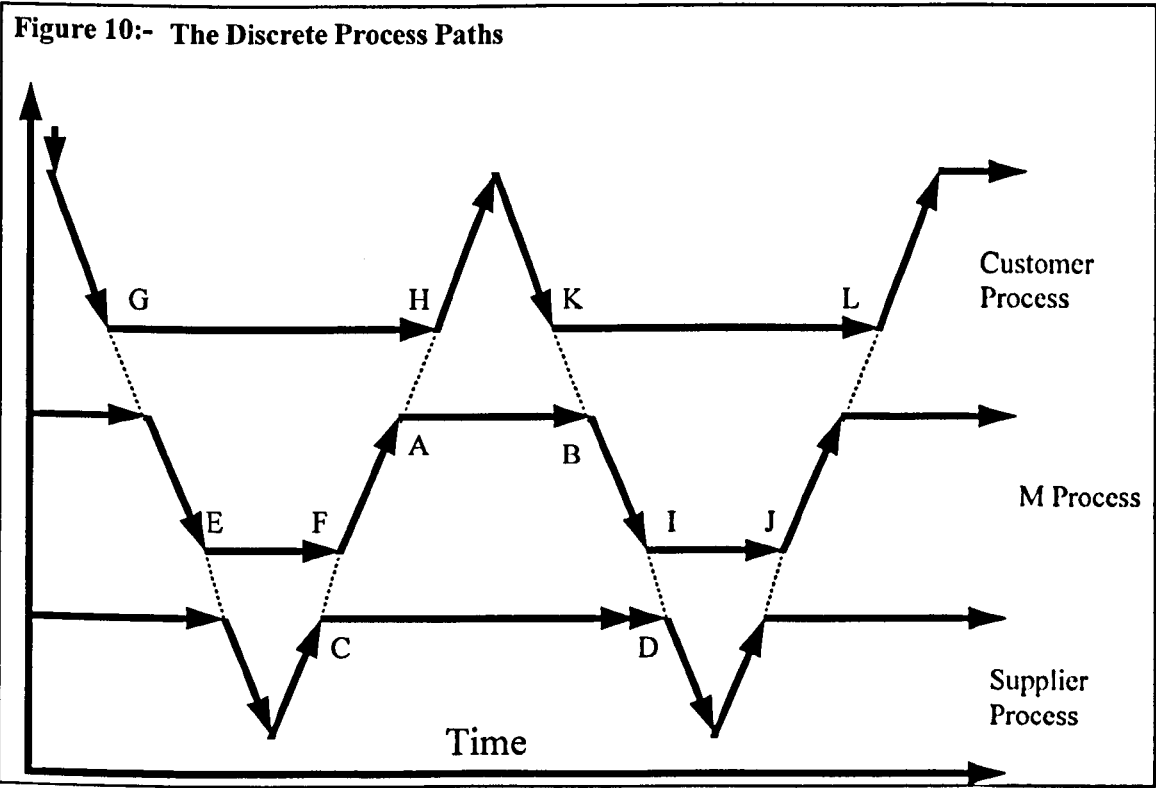
As described, the life cycle model is linear and sequential. It is presented as predictable and controllable. However as occurs in a free market, each *need* is capable of being met by alternative solutions. It can be appreciated that there are many supply chains competing with each for various positions in the overall chain. This selection occurs during the initial definition phase. The real definition process becomes non-linear. This does not invalidate the model however but merely increases its complexity and makes the whole enterprise behave in a non-linear way.

Whilst not included explicitly in this section the application of 'Chaos' or Complexity theory to the behaviour of processes in a free market environment draws excellent parallels with the processes of nature. The Demming cycle (Plan,Do,Check,Adjust) is mirrored by mutate, replicate, compete, mutate etc. This is the Darwinian or Evolutionary view of the world which applies in a free Market Economy. Much time has been spent gleaning understanding from the workings of biological systems and the storage and use of genetic information (DNA). The process structures in a business enterprise are

analogous to the processes at work in natural systems from single cells to multi-cellular organisms. This is considered a valuable field for further study.

3.3 The Variation of Life Cycle Timescales with the Level of Product in the Food Chain.

Figure 10 expresses the variation of active lifecycle timescales experienced by each subsystem depending on its level or position in the food chain.



Contrasting a supplier process and a customer process the following observations can be drawn.

- 1) The lower down in the food chain at which a process exists the time between the *analyse/synthesise* activity and the *Instruct/Execute* activity

increases i.e. $AB > CD$. This has implications for the storage and transfer of data between these activities.

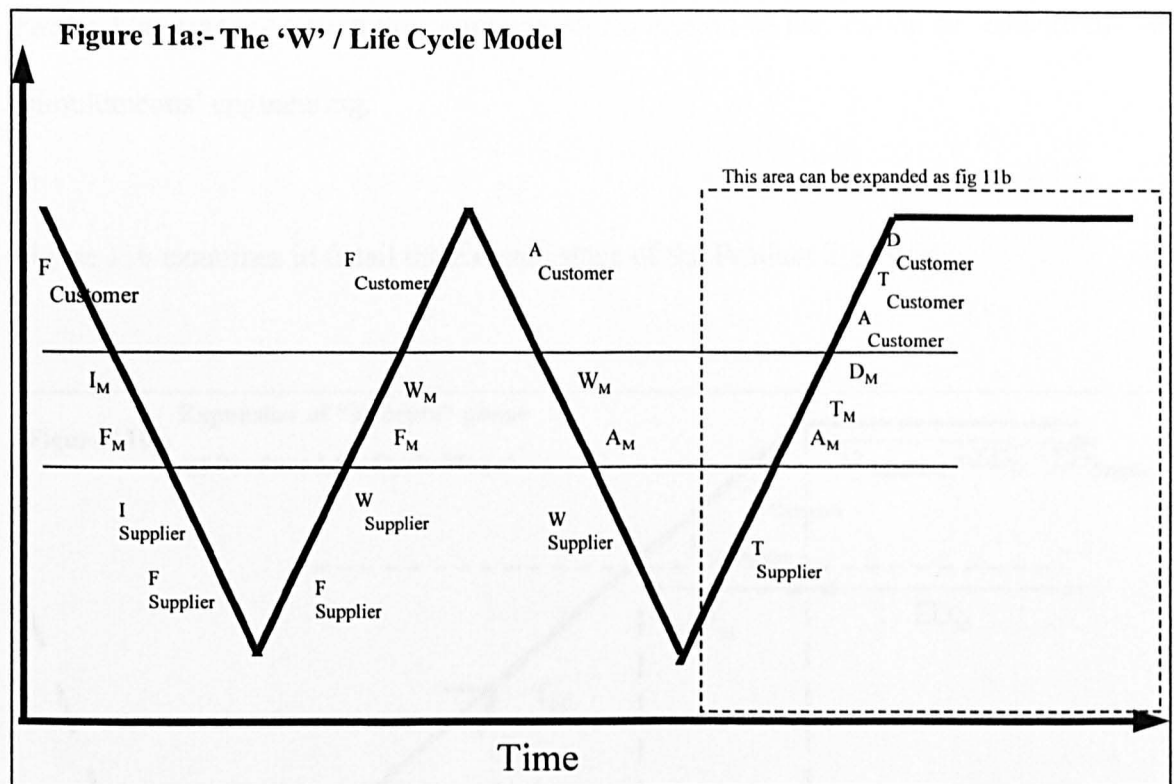
2) As the level in the food chain increases, the time between the *analysis* and *synthesis* stages of the process model increases as does the time between the *instruct* and *execute* stages.

i.e. $GH > EF$ and $KL > IJ$. The discontinuity inherent in these processes at higher levels has practical implications, particularly when relaying manual systems of working with human memory playing a major part in data storage.

3) The supplier is under increasing timescale pressure from the customer due to the inherently decreasing timescales available to a supplier.

3.4 Combining the Concepts of the "Domino" with the 'W'.

Presented so far is firstly the Domino model- A model that provides a means to describe and analyse an enterprise. A second model ; the "W"; introduces the concept of time into the overall product lifecycle description. It is of benefit to examine these models simultaneously in order to describe which part of the enterprise or complete business process (I,F,W,A,D or T) is happening at any given moment in the life cycle of a product. An individual enterprise in the 'W' model is represented by a horizontal 'slice' across the entire model. Figure 11a represents the combined Domino and 'W' models.

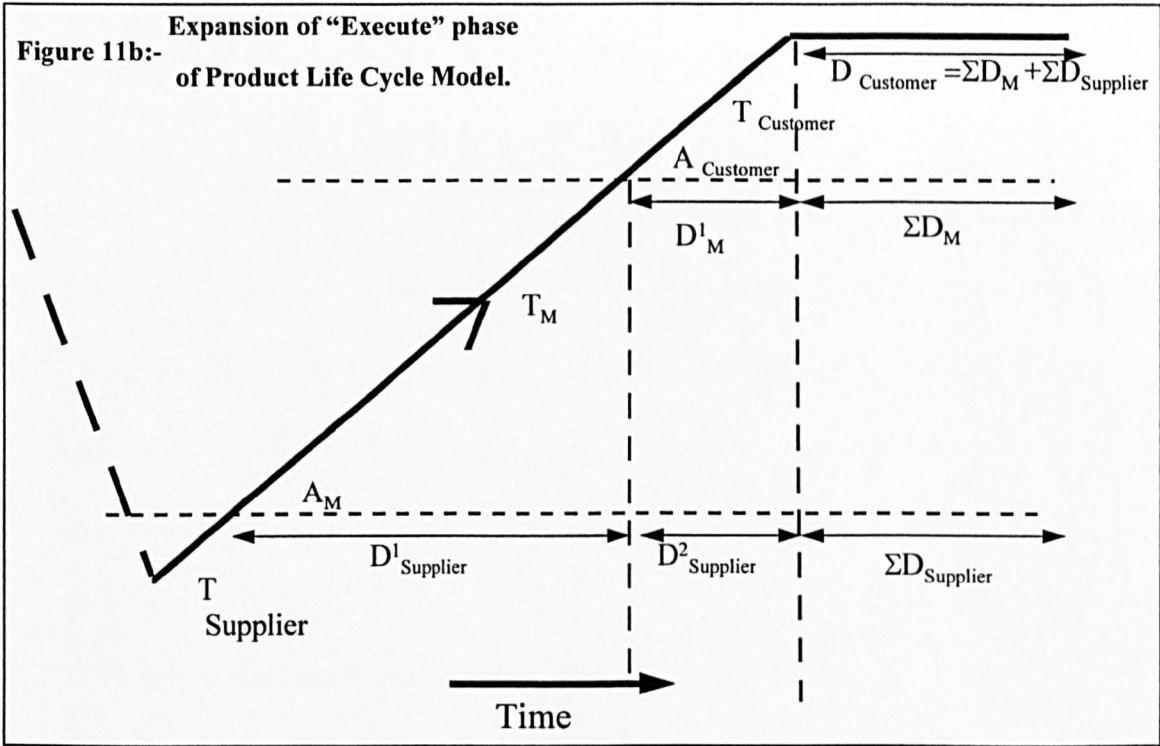


Examining figure 11 a we see that this describes the stages of a process that are occurring at various points within the life cycle of a product. Figure 11a shows three levels of processes. A supplier process (S suffix) and a customer process (C suffix) sandwiches a particular "me" process that is being examined. (M suffix) Hence the I,F,W,A,T,D nomenclature indicates which of the domino processes is happening at any given time in each of the three levels.

Examining the first leg of the product life cycle it can be seen that the decomposition of customer *need* down through the food chain causes all processes to operate together in the

Find a Way stage. As such this is merely an expression of the notion of ‘concurrent’ or ‘simultaneous’ engineering.

Figure 11b examines in detail the *Execute* stage of the Product life cycle.



The product produced by the lowest process in the food chain starts to provide its functionality when acquired by its customer and assembled further towards the final product. The functionality which it delivers at this stage might only be partial. A simple real life example illustrates this point. A set of wheels delivered to a car manufacture will start to provide support for the rest of the car as soon as they are fitted to the axles. However it is not until the car is completed that the full functionality of the wheels is delivered, as the car actually moves forward under its own power. Figure 11b expresses the notion that the separate elements of sub product functionality are summed together to deliver the full product functionality at the time of final product deployment.

3.5 Summary

The 'W' model provides a tool by which to examine the temporal aspects of an enterprise.

The model is of greatest benefit when used in conjunction with the nomenclature of the Domino Model.

Chapter 4

4.0 Control Model of a Process.

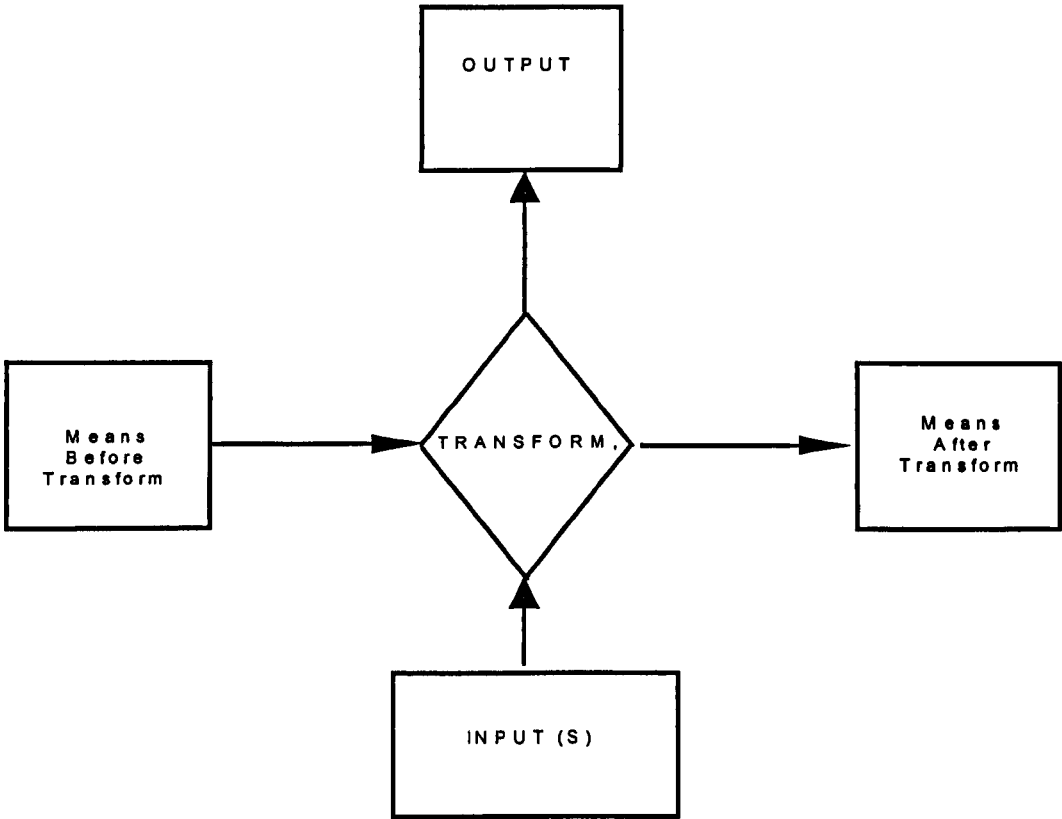
The third and final model that requires explanation in this section of the submission has been called the Process Control Model. Examining the pre-requisites that were set out for the creation of models it can be seen that neither the 'Domino' or 'W' model provide the user with the conceptual understanding of the levers of Business Process Re-engineering. The fundamental notions of Total Quality Management captured in the Demming cycle viz.-Plan, Do, Check, Adjust have not been adequately captured. This cycle can be more aptly expressed as a sequence of Design, Execute, Compare/decide and Redesign. The nomenclature of the Domino can be brought in line viz. F= Design= Plan; T= Execute=Do.

4.1 Process Control Model

In figure 12a we see the basic transform model. This requires expansion in two main areas. The model, as expressed, is open loop. There is no feedback mechanism to check that the output of the process meets requirements or an agreed standard. Figure 12b defines and 12c adds the concept of a control loop to the process model. There is a requirement to provide further understanding of what constitutes the *means*. The *means* is the combination of the building blocks which comprise the system that enable the *Transformation* of the *input* into the *output*. The process control model aims to provide a

frame work by which these blocks can be conceptually isolated, expressed and thus examined.

Figure 12a:- Basic Transform Model



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Figure 12B :- Basic Transform Control Loop

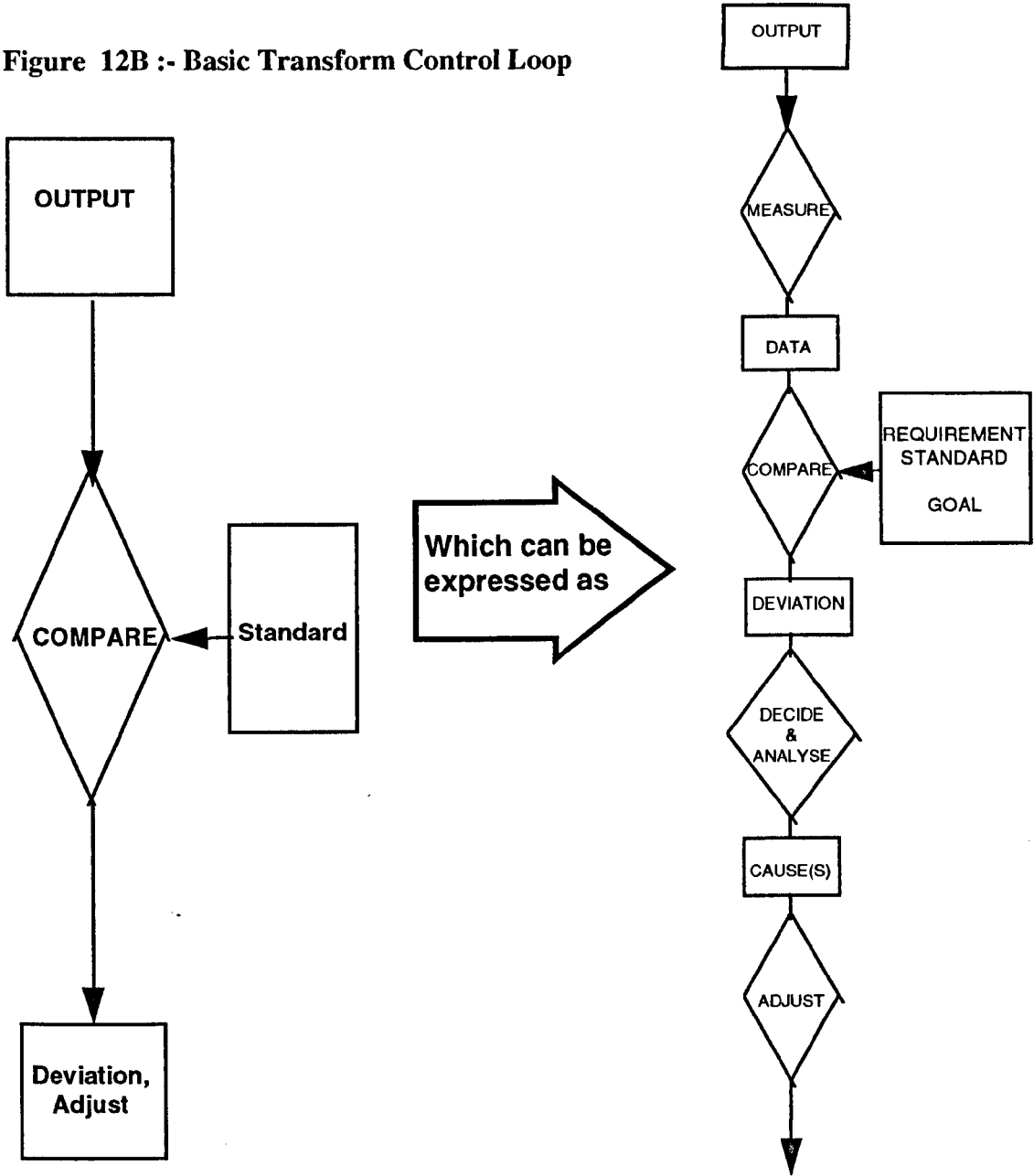
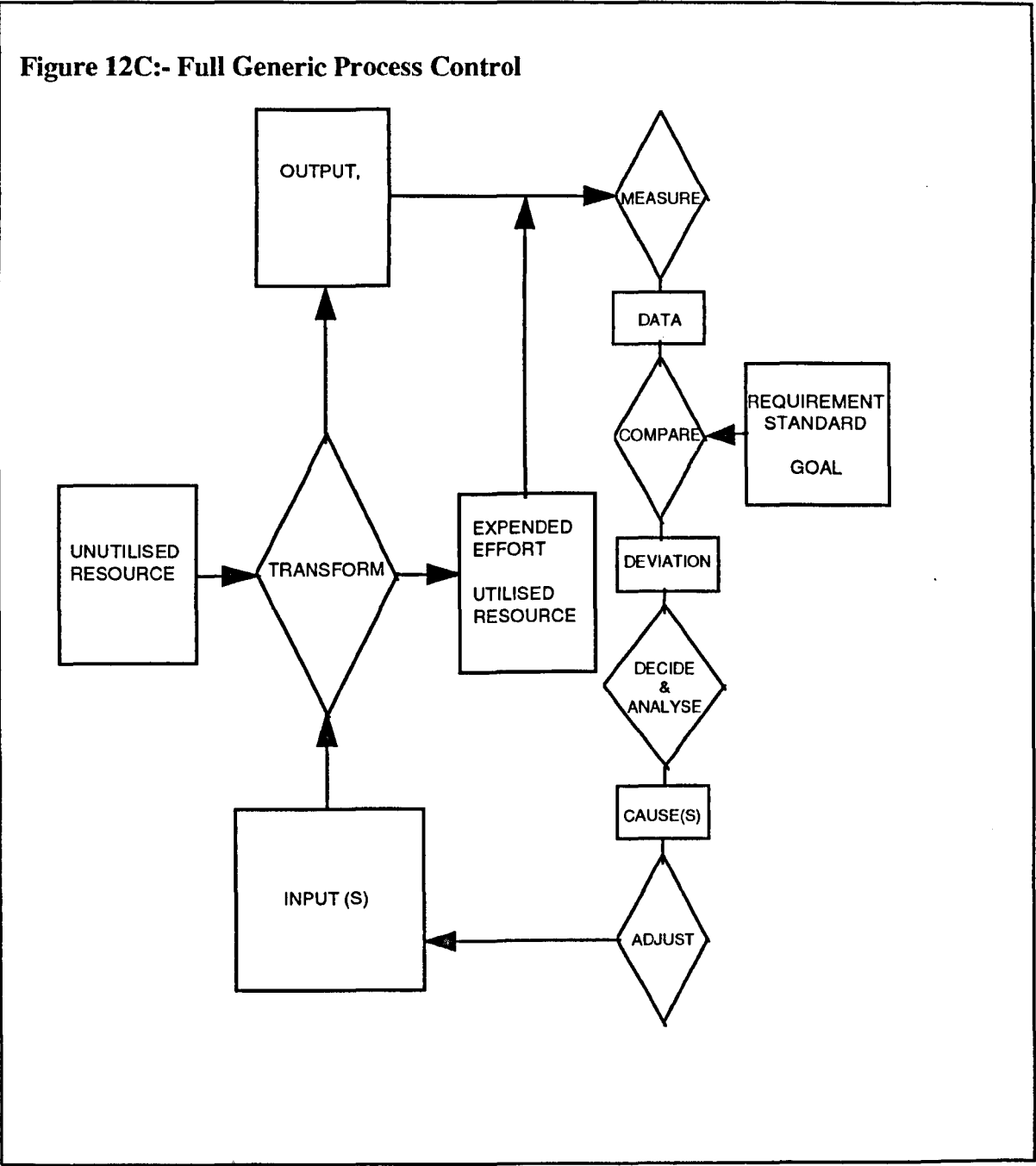
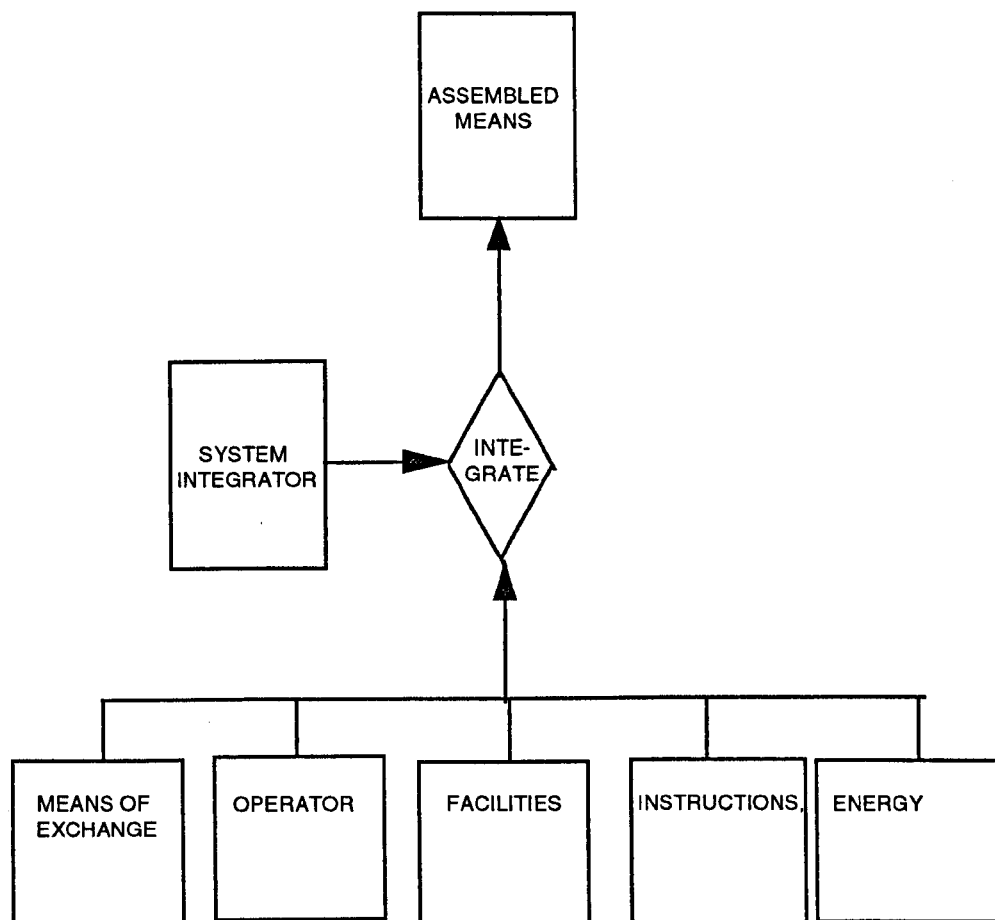


Figure 12C:- Full Generic Process Control



There are 5 elements which go to make up the *means*. These are given the titles of *Men*, *Method*, *Machine*, *Motivation* and *Money*. Figure 12d represents the expanded *means*. Figure 12e describes the generic control system model by applying the control loop to the expanded models.

Figure 12D:- Generic Expression of Assembled Means

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Figure 12E :-Full Generic Process Control

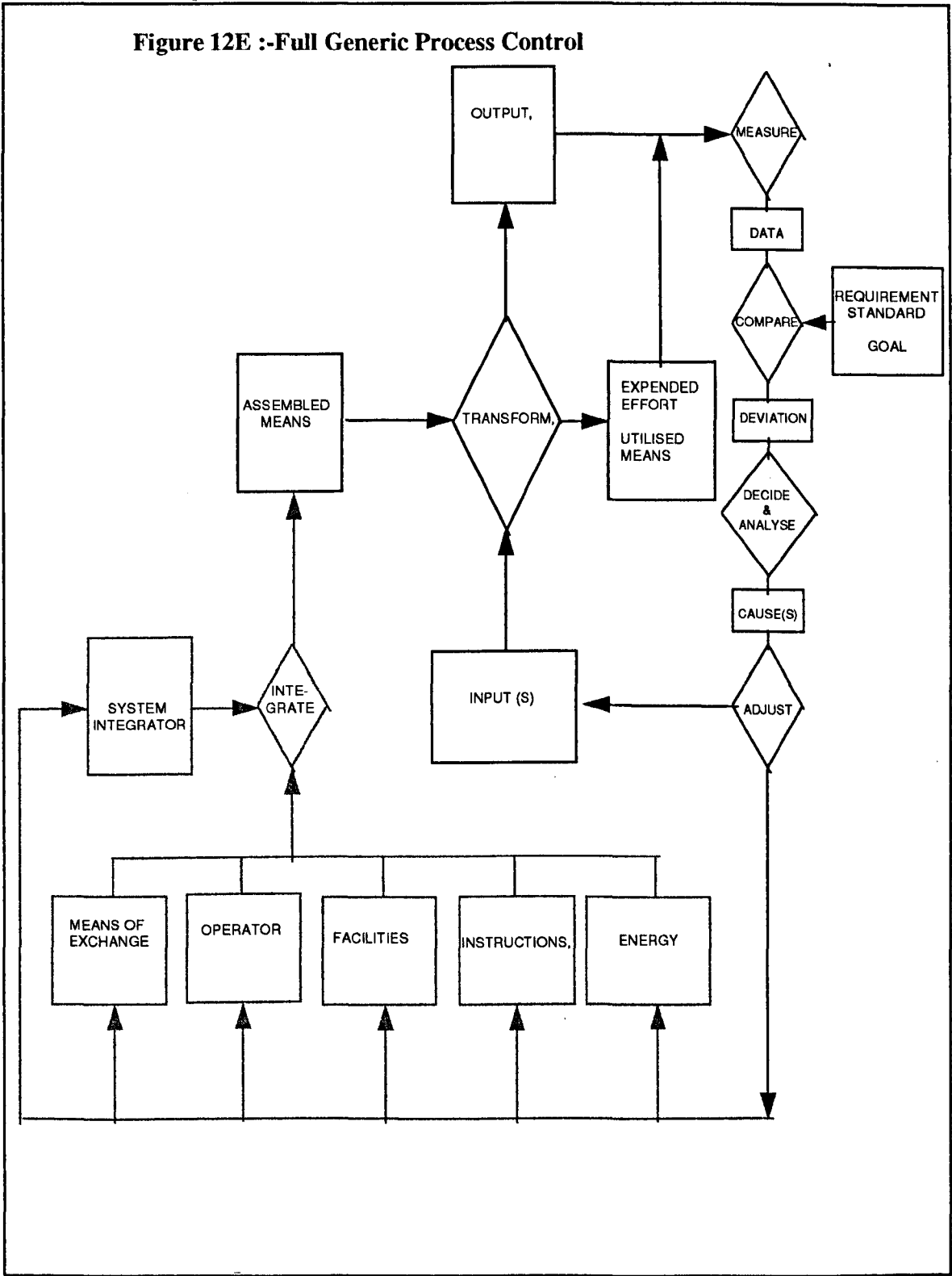


Figure 12F:-Applied Process Control Model

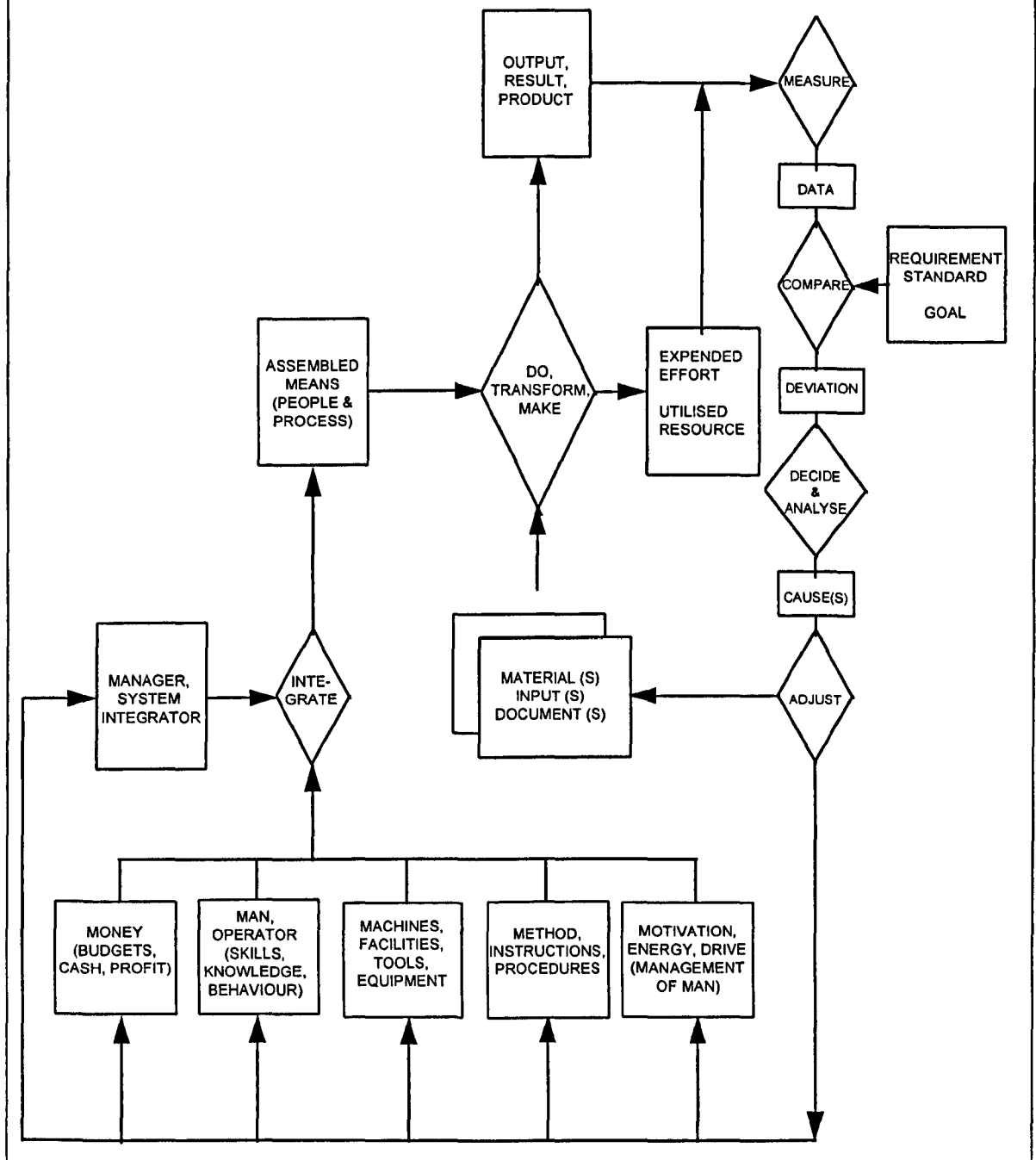


Figure 12F summarises the process control model as utilised in the Rolls Royce Aerospace Group giving various examples of the types of inputs which characterise the various individual processes. These examples prompt understanding when modelling any particular process.

Together with the *input material* these can usefully be termed the 6Ms. However in order to fully explain the universal application of this model the 6Ms need to be expressed in more fundamental terms. Each of the 6Ms will be explained in turn, firstly at a conceptual level and then with reference to the processes within Rolls Royce Aerospace Group business. Described in these terms they are in themselves fairly self explanatory.

4.1.1 Operator => Men (M₁)

For any process to function an operator is required at some level. In a fully automated process the operator will not be a human being. Being able to identify the operator is very important when addressing the workings of any process. The operator in the majority of processes within the Rolls Royce Aerospace Group process has been identified as *Men*. The role of the *men* within a process can be extremely varied. The same individuals can also assume the role of system integrator and/or motivation in addition to being the operator. When using this model to understand and express the *means* of a process the role or function of the *men* must be rigorously defined.

Let us take a simple example to illustrate the roles further. Consider the *men* who operate machine tools on the shop floor. These *men* will obviously have a significant effect on the efficiency of the process. However these same *men* within a manufacturing cell environment might also be integrating the whole process and providing their own motivation when working in self directing teams.

Taking Rolls Royce Aerospace Group as a whole the *Men* would simply represent all of the employees of the said organisation. Each individual or group of *men* will possess skills, knowledge and behavioural characteristics i.e. competencies which are deployed in the various roles during the execution of the complete range of processes. The isolation of these competencies aids the understanding of the function of the process and the men within them.

4.1.2 Instructions => Methods (M₂)

Taken at a conceptual level a process is always carried out to a set of instructions. These dictate the way in which a process is performed and are often referred to within the Rolls Royce Aerospace Group case as the 'method'. The method encompasses the instructions and the procedures which are adhered to in the execution of the process. These instructions and procedures reflect the inherent paradigm found within a company and thus reflect the company culture. The way in which a process is carried out will obviously have significant effects on its efficiency. Being able to focus on these procedures and instructions allows efficiency and effectiveness to be examined.

4.1.3 Facilities => Machine(M₃)

The facilities describe the physical hardware and environments that are required in order to carry out the process. For any individual process this will obviously vary but might include hardware such as IT equipment, office space or machine tools. Within the Rolls

Royce Aerospace Group this facet has become known as Machines . Again the machines and environment can have a tremendous effect on the performance of a process.

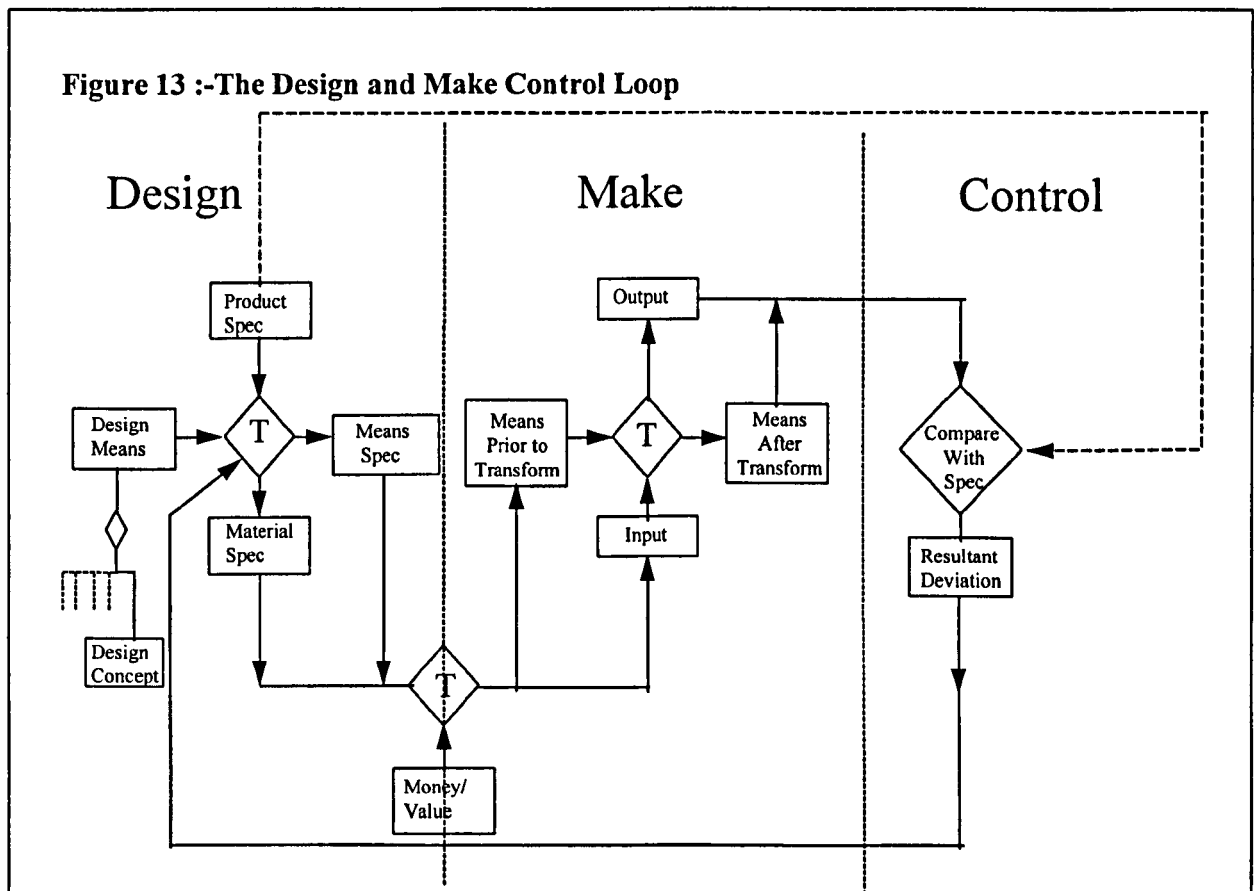
4.1.4 The Provision of Energy => Motivation(M_4)

A process involves a change from *input* to *output* and thus requires energy in order for it to happen. Being able to analyse the source and nature of this motivation is important when examining a process. This driving force can manifest itself in many forms. It can be the motivation that causes men to function. Alternatively it could be the physical power required for certain manufacturing processes. For the overall Aerospace Group Process it is the requirement to provide a return to the shareholders on funds invested which drives the enterprise.

4.1.5 Means of Exchange => Money(M_5)

The fifth element of a process model is the means of exchange of value. This is usually money and is normally required wherever the means and material (the other 5Ms) are acquired. By introducing this aspect into the model it creates simultaneously an economic model to describe the financial workings of a process by relating exchange of value to physical activities. The notion of financial control is also dealt with . The difference in monetary value of the means before and after the process has occurred is equal to the cost of the product. Money provides a way of exchanging the value of say “one man day” of effort and translating this into the cost of the product. This exchange of

value notion is further illustrated in figure 13. This simply illustrates how the exchange of value is then means necessary for a purchase transaction which connects the design and make process. Money enables the transformation of virtual means to an actual means. The timing of the flow of money i.e. cash may be displaced and replaced by a promise i.e. the creation of a debtor and creditor.



4.1.6 The Input =>Material(M₆)

The input to any process will be the output from another process lower down in the food chain. The model also expresses the notion that the input comprise the output of several processes. Such an example might be the assembly of a turbine module from turbine blades, discs, casings and vanes. This sixth M is the material which has to be transformed into the product by the means of the process.

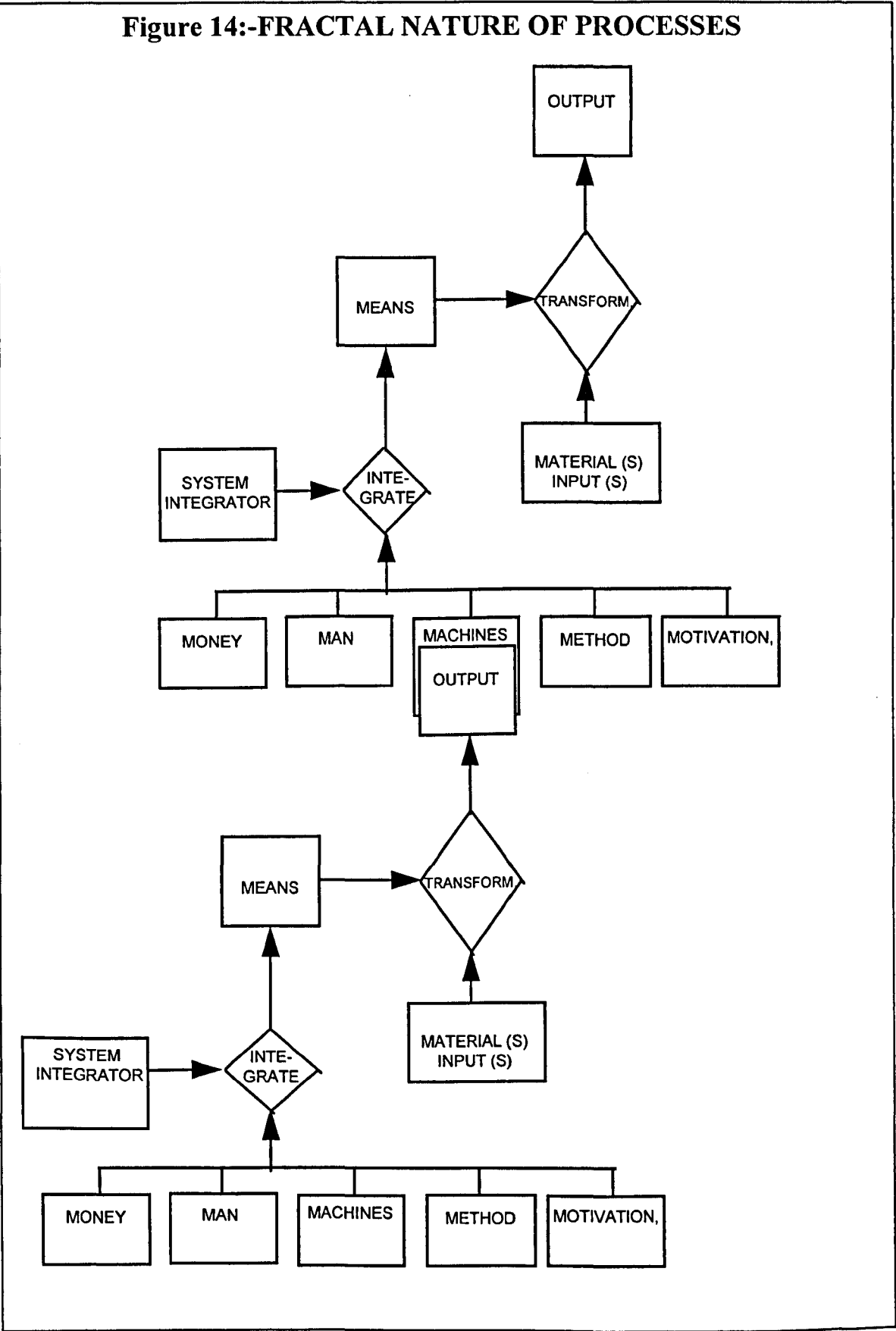
4.2 The Role of the Systems Integrator.

Within a process it has been shown that the main levers of control are the 5Ms and the input (6th M) to the process. The role of the system integrator is to manipulate either during design or operation these levers in order to ensure the satisfactory performance of a process. This performance can be measured in terms of the degree of conformance attained by the product. The ability of a process to perform according to a required standard and then evolve should this standard not be met is fundamental to Demming's *Plan, Do, Check, Adjust* quality cycle. The output of a process should be measured and then compared to an agreed standard. If there is any deviation from this standard then the causes for this must be sought and identified. With the knowledge of the source of deviation from standard it will then be possible to adjust any of the 6 Ms in order to meet the required standard. Hence an easy methodology by which to perform *Root Cause Analysis* is also provided by this model

4.3 Fractal Nature of Processes

As explained in previous process models the universal process nature of the business results in a fractal type relationship between the many processes. The process control model is capable of expressing this. It needs to be remembered that any of the boxes within this model is simply the output of another process. Expressing this in terms of the model is illustrated in figure 14. If this is done in detail for many processes then the resultant model can become a very complex. Hence this should only be pursued to the extent where the resultant model continues to aid understanding of relationships.

Figure 14:-FRACTAL NATURE OF PROCESSES



Appendix A

Supporting Reports and Submissions

The following documents reflect the application of the work detailed in the main submission. They are examples of how the methodologies described have been usefully employed within the Rolls Royce Aerospace Group

Reports.

- 1 Rolls Royce Aerospace Group Quality Manual.
- 2 Rolls Royce Aerospace Group Training for Quality Teaching Pack.
- 3 Project 2000 :- The improvement Process User Guide.
- 4 List of Project 2000 Reports.
- 5 P2067 CEB Planning the Business Task force Final Report.
6. P2101 Factory Definition Final Report.
7. Business Process Re-Engineering " A Natural Approach" :- Proceedings for
BPRC Forum One held at Warwick University 19/9/95
- 8 P2068 Identify the Need and Win the Order Task Force Report.
- 9 P2042 The Final Report of the Functional Behaviour Task Force.
- 10 P2041 The Product Definition and Verification Process:- General Discussion.